AQUIFER TESTING REPORT

Gunnison Copper Project

Revised June 2017

Excelsior Mining Arizona, Inc.

1. Introduction

This report presents the results of the interpretations of hydraulic tests for the Gunnison Copper Project area proposed for in-situ mining, located 62 miles east of Tucson, Arizona. The purpose of this report is to provide a technical basis for the quantification of hydraulic parameters for site characterization in support of Excelsior's Aquifer Protection Permit (APP) and Underground Injection Control (UIC) Permit applications. Pumping test data has been collected over two phases, 2011-2012 and 2014-2015 by Excelsior and their consultants, and the resulting analyses have been reviewed by Clear Creek and Associates (2015). This report has been prepared as an exhibit to the groundwater modeling report that will be appended to the APP and UIC applications.

The analyses presented in this report are based on standard methods developed in the groundwater industry. These methods are applied to data collected at the Gunnison site during the hydrological investigation phases which culminated in the siting, drilling and testing of 27 NSH (North Star Hydrology) wells and boreholes that were designed and installed for the purpose of understanding and quantifying the hydrogeological conditions of the site. Interpretation of the field data was performed with the AQTESOLV (v. 4.5) software by HydroSolve, Inc.

This report is organized as follows:

- Section 1 which provides an introduction and background of the project
- Section 2 presents the theory and mathematical foundation for the test well analyses. A brief discussion of each test and application of this theory to the aquifer test at the Gunnison Site is presented in Sections 2.4 through 2.6.
- Section 3 describes additional hydraulic testing performed at selected wells using isolation packers and spinner logging tools.
- Section 4 addresses the porosity of the fractured ore body.
- Section 5 summarizes the data and provides practical applications for it. Table 3 contains the results of hydraulic parameters generated at the site.
- Section 6 provides references.

1.1 Background

Excelsior has undertaken field studies to characterize the hydrogeologic conditions at the proposed Gunnison Copper Project site. The proposed mine site is located in the Basin and Range Physiographic Province of southern Arizona, on the western edge of the Wilcox basin and is 17 miles east of the town of Benson, Arizona along interstate 10. The site name originates from the Gunnison Hills, a sharp and narrow ridge of Paleozoic limestone which separates the site as a sub-basin from larger basin centered around the Wilcox Playa.

The rock units in the study area range in age from Precambrian to Quaternary. The basement rock is comprised of the Pinal Schist, Lower Precambrian in age. The mineralized ore is hosted by the Abrigo (Upper Cambrian), Martin (Upper Devonian) and, to a limited degree, Escabrosa (Lower Mississippian) Formations. Bounding the sub-basin to the east are the Horquilla Formation of the Naco Group (Middle Mississippian) with outcrops in the Gunnison Hills, and to the west the Texas Canyon quartz monzonite (a Lower Tertiary intrusive unit), cropping out as the Texas Canyon Summit. The bedrock formations are uncomformably overlain by Basin Fill of upper Tertiary and Quaternary age. The thickness of the Basin

Fill over the site varies from 250 to 600 feet and is increasing in thickness towards the Gunnison Hills. The site is nestled in the northern part of this sub-basin and straddles I-10.

Excelsior retained Clear Creek Associates of Scottsdale, AZ, to prepare the APP and UIC applications for the Gunnison Copper Project. As part of this characterization effort, hydraulic testing of 24 wells was performed and water level responses were monitored in 75 observation wells. For the purpose of monitoring, all available accessible boreholes were considered, including the designated hydrology wells (NSH), diamond core holes (NSD), metallurgical exploration bores (NSM), as well as accessible boreholes from previous exploration drilling programs: MCC (Magma), CS (Cyprus Superior), T and S wells (Quintana). The 24 locations selected for hydraulic testing cover the range of typical hydrogeologic conditions observed at the site and include tests in basin fill, fractured zones within the different geologic bedrock units, fault intersects, massive blocks with limited faulting and highly mineralized zones as well as un-mineralized rock formations. Locations of the NSH wells tested under this program are shown in Figure 1. The locations of observation wells used during pumping tests of individual NSH wells is shown in Figures 31 through 48. The following sections present an overview of the theory and methods of interpretation and analytical results for these aquifer tests.

1.2 Equipment

For the purpose of aquifer testing, three types of pumps were needed because of different bore diameters, depth of lift and anticipated yield. On 6-inch well completions, the Grundfos model 85S200-16 was used with 20 horsepower (hp) motor and 3-inch discharge pipe. This pump can lift 30 gpm from a depth of 850 feet. For 4-inch wells, where adequate flows were expected based on observation of borehole development observations, the Grundfos 40S100-30 was deployed. This is a 10 hp submersible pump with a 2-inch discharge line and a maximum lift of 800 feet at a discharge rate of 10 gpm. And lastly, for low yielding wells the submersible Grundfos 10S20-27 was used. This pump is capable of pumping 5 gpm from 700 feet using a 2.5 hp motor. All thee pumps have a built-in reverse flow check valve, preventing water in the discharge pipe from draining back into the borehole at pump shut down.

Recording transducers were deployed in both the pumped well and in the observation wells. The transducers included Level Troll© by InSitu, models 400, 500, and 700. The model number designates the cable length. All transducers are air-vented and the readings were compensated for barometric fluctuations with data collected from a Baro Troll data logger. The Baro Troll was placed in an observation well during each test and suspended above the water level to closely approximate the temperature and barometric pressure effects at the water table. Manual depth to water readings were measured to the nearest 0.01 feet using water level sounders by Heron Instruments, model Dipper T with 1000 feet of reel.

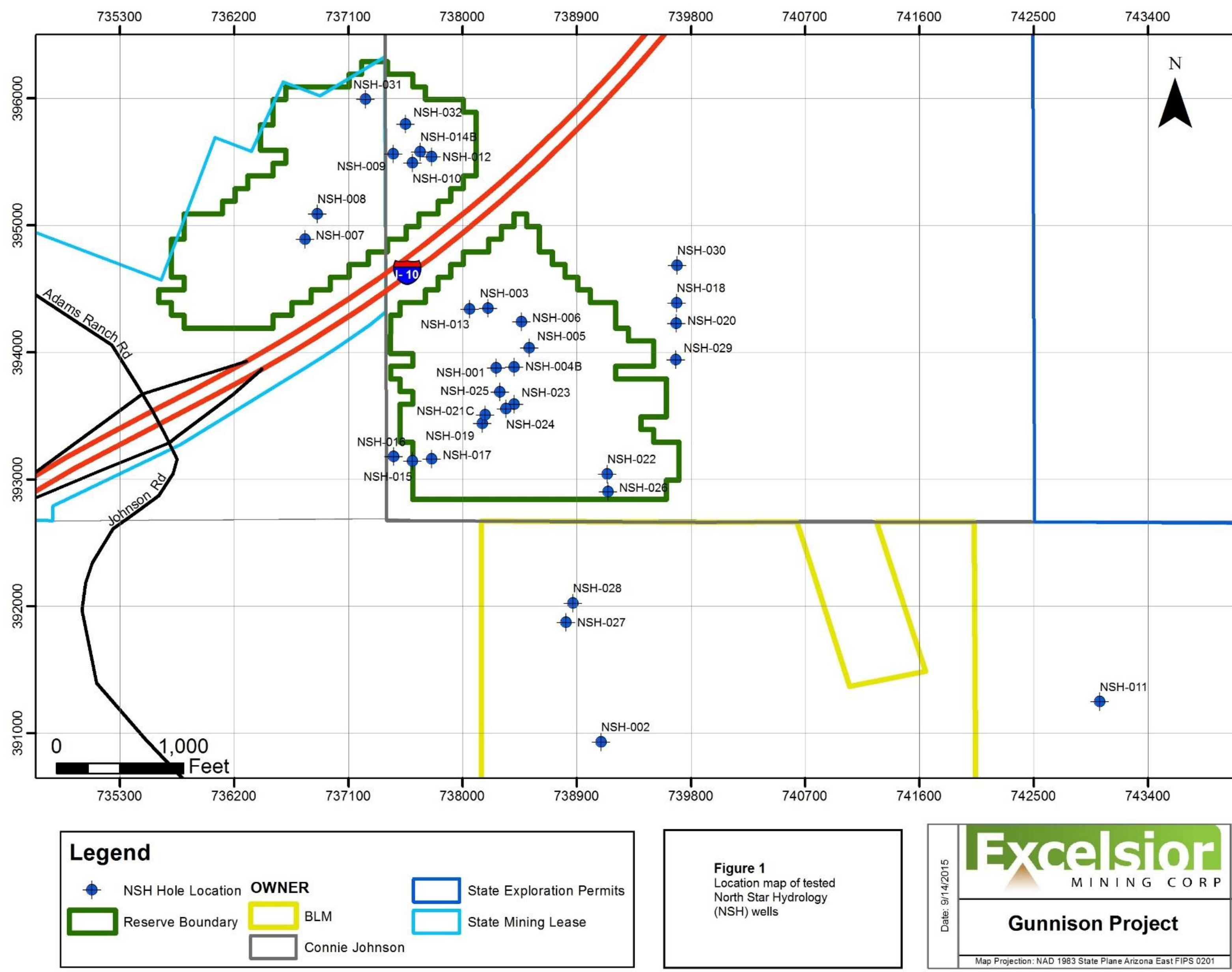


Figure 1
Location map of tested North Star Hydrology (NSH) wells

2. Theory and Methods of Interpretation

Hydraulic well testing provides a means of evaluating the properties of hydrogeological formations. Quantification of these properties is essential to an in-situ recovery mining process where recovery (of soluble copper in this project) is achieved between an injection well and a recovery well. In the process of a hydraulic well test, a known signal (usually a change in flow rate) is applied to the formation and the resulting signal or response is measured (usually in terms of a change in pressure or drawdown of water level). A hydraulic test interpretation is therefore an inverse problem in that the formation parameters are inferred by comparing a simulated model response to the measured response. The formation parameters are derived by adjusting the analytical solution model parameters to obtain a simulation that best matches the measured drawdown data.

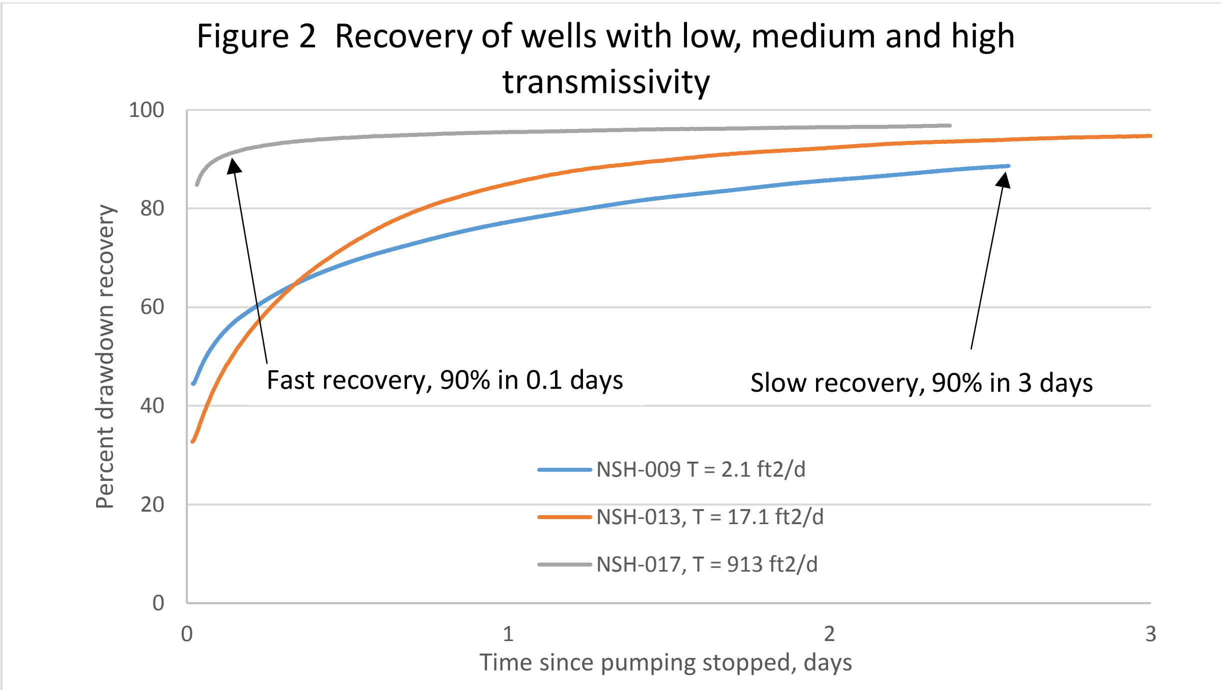
The overall methodology for the hydraulic well test analyses at Gunnison has three components:

- A step drawdown test whereby the pumping rate is incrementally increased over four periods of same length (typically 2-hours per step)
- This stage is followed by constant rate test where the discharge is equal to rate attained during the last step (Step four). Duration of this stage is 5 days, and
- A recovery test where the pump is shut down but water level monitoring continues in the pumped well and in the surrounding observation wells. Duration of this stage was 3 days.

Whereas the residual drawdown recovery is performed at the end of the pumping test, it is the first record to be analyzed in order to obtain an initial estimate of transmissivity (T). The recovery from the pumped well itself does not reveal information about storage properties of the aquifer, but it does convey information on how quickly water returns into the cone of depression generated by pumping. Recovery analysis is a good starting point when comparing responses in multiple wells, because each pumped well will display recovery regardless of its depth, diameter, yield or connectivity.

2.1 Analysis of Recovery Period

The analysis of drawdown recovery is based on the assumption that upon pump shutdown, the water level in the pumped well will rise to its pre-pumping level and the amount of water recovering to the well corresponds to that of the withdrawal that took place at a known flow rate over a fixed period of time. Recovery curves for high, low, and average yielding wells are shown in Figure 2. The T value of each of the three wells is directly proportional to the amount of time needed to recover the bulk of the drawdown. Figure 2 shows that even the least producing well, NSH-009, recovers 75% of the drawdown in 20 hours (0.83 days). This relatively good hydraulic recovery, despite the very tight rock formation (marble and limestone), is indicative of the presence of saturated fractures that convey sufficient amount of water to replace the water extracted from the well during pumping. When the flow rate prior to the recovery period is variable, pumping history is included in the analysis using the principle of superposition of a number of different but constant flow rates with different durations. This is obtained through the use a transformation of the time variable by employing the Agarwal (1980) procedure, which has been activated in AQTESOLV when performing recovery test analyses of multi-rate tests.



The assumptions in the application of the Theis (1935) recovery method are:

- aquifer has infinite areal extent
- aquifer is homogeneous, isotropic and of uniform thickness
- pumping well is fully penetrating
- flow to pumping well is horizontal
- aquifer is confined
- flow is unsteady
- water is released instantaneously from storage with decline of hydraulic head
- diameter of pumping well is very small so that storage in the well can be neglected

In a sloping stratigraphy with a fracture-dominated matrix, the assumption of horizontal flow to the pumping well will not be met. However, at the late times of the recovery, it is postulated that due to the high fracture frequency, flow towards the cone of depression will assume a general horizontal direction since no aquifers exist above and below the bedrock aquifer. No provision is made for water level rises in the pumped well under pumping conditions. To avoid these water level rises (when pumping is reduced, when pump is lowered during the test, or when the pump temporarily shuts down), pumped well recovery observations were made at the end of a pumping test and the pump was left in the bore for the duration of the recovery test. The test on NSH-026 had pump problems six hours into the pumping. Discharge rate had to be reduced from 100 gpm to 13 gpm and then be ramped up to a final 75 gpm to keep the pump intake submerged. In the recovery analysis for NSH-026, the variable pumping has been taken into consideration when quantifying the well's transmissivity.

Table 1, below, summarizes the transmissivities from the pumped wells.

TABLE 1. Recovery test results, Residual Drawdown Test Transmissivity in ft^2/day

Well ID	T (ft^2/d)	Q_{max} (gpm)	H_{max} (ft)
NSH-001	32	30	84
NSH-002	2000	44	57
NSH-003	48	8	182
NSH-004B	210	15.5	120
NSH-005	1245	36.3	57
NSH-006	1985	6	0.5
NSH-007	64	13	168
NSH-008	5	8.4	175
NSH-009	2	6	252
NSH-010	9	4	49
NSH-011	injection	-5.5	N/A
NSH-013	17	10	122
NSH-014B	11	3.7	442
NSH-015	1010	85	76
NSH-016	710	15	60
NSH-017	913	170	154
NSH-018	1995	32	5
NSH-019	699	139	192
NSH-020	3715	32	10.4
NSH-021C	198	150	180
NSH-022	2	2.7	277
NSH-023	39	20	222
NSH-024	73	30	251
NSH-025	2	3	220
NSH-026	400	67	152
NSH-027	83	60	163
NSH-028	3	2	112

The reported transmissivity values from the recovery tests display a high degree of variability on the order of three orders of magnitude. The drawdown recovery plots are shown in Figure 5 through Figure 29. The range in slopes and shapes of the recovery curves is wide because transmissivity is a bulk property without consideration of how and from where groundwater is replenishing the developed cone of depression. A rough estimate of hydraulic conductivity (K) can be made by dividing transmissivity (T) by the thickness of the hydraulic interval (b) such that $K = T/b$. The hydraulic interval is the vertical length between the bottom of the well screen and the initial water table. In uncased holes, it is the length of the water column (from total depth to initial water table).

Refinement of the analysis is achieved by investigation of the responses reported by observation wells some distance away from the pumping well. A well pair represents a volume of aquifer between the stressed (pumping) well and the observation well. Hydraulic influence exerted by the aquifer is then analyzed in higher detail with the following hydraulic conductivity analysis.

2.2 Analysis of Drawdown Period

The difference in hydraulic head in the pumped well or in the observation wells at the start of the test and at some time after the test begins is referred to as drawdown and is measured in feet (ft). Test well discharge or well yield is the amount of flow extracted by the pump and is given in gallons per minute (gpm). During well development procedures, initial estimates of the well yield were made and used in the design of the aquifer tests. The objective of the test is to stress the aquifer sufficiently to generate a response that is pronounced enough to propagate through the aquifer and assess its hydraulic properties. Only when sufficient hydraulic head change (not less than one foot) was achieved in an observation well during the drawdown period, the available water level traces were analyzed as a pumping test. Otherwise, the data were not used in the interpretations and the observation well was considered non-responsive.

The working hypothesis is that the aquifer system, while composed of fractured rock, is fragmented to such a degree that it behaves like a porous medium with voids in both the fractures as well as in the rock matrix. This type of aquifer system can be analyzed with the dual porosity models in AQTESOLV. The hypothesis is supported by the fact that the core samples from exploration bores display natural fracturing on the order of one foot intervals over the full thickness of the oxidized ore body. The maximum thickness of the ore body is approximately 830 feet, and the responses to pumping propagate over similar distances. This suggests that while the bulk of the flow is occurring in discrete fractures, the manifestation of flow as represented by drawdown and observed at a scale of hundreds of feet, is comparable to that of pumping from a porous medium such as sand.

In an analysis of the main pumping flow period, the source signal is assumed to be in the form of an instantaneous pressure change from undisturbed pre-pumping condition. Since pumping tests evaluate a much larger volume of the aquifer than what is stored in the well bores, they are the most commonly accepted methods for determining representative aquifer properties at sites with groundwater monitoring wells. This distinguishes these tests from the recovery analyses from the previous section which do not rely on monitoring wells. Drawdown test analysis can be performed to determine the transmissivity between the pumping well and the observation well. By comparing the rate of drawdown in the pumped well to the rate of drawdown in an observation well, estimates can also be made of the storativity of aquifer, using transient drawdown propagation solutions.

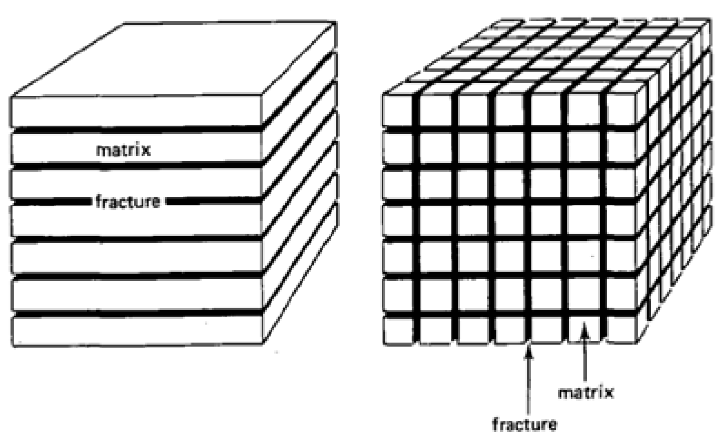
In fractured bedrock, such as encountered at the Gunnison site, the transmissivity varies with the direction from the pumped well. High intensity fracturing is associated with fault zones at the site. An observation well that shares the same fault zone with the pumping well will respond with more pronounced drawdown than an observation well that is located outside of that fracture zone. The well-pair orientation with respect to faults explains why some tests register drawdowns of 10 feet at 763 ft distance away, while other observations show zero drawdown effect at 433 feet distance from the pumped well. Well pair orientation, expressed as azimuth from 0 to 360 degrees, is therefore being reported for each well pair when induced drawdown in an observation well has been recorded.

The presence of fracture flow is evidenced by the alignment of drawdown data on a straight line when plotted against square root of time (on a log/log plot). This relationship, described by Jenkins and Prentice (1982), has been built into AQTESOLV and is used to screen for appropriate curve matching technique when analyzing aquifer test data. For a purely linear flow system the drawdown dependence on square root of time will have a slope of unity. Figure 30 shows the drawdown observed in well J-05 while NSH-015 was being pumped at 85 gpm. The match between observed data and the linear flow model is evident after one day of pumping.   The plotted line has a slope of 1:1, which is an indicator of a linear flow system.

Another line of evidence for fracture flow is the establishment of relatively steep cones of depression when approaching steady-state pumping. The maximum drawdown caused by a pumping well was observed at NSH-008 when NSH-007 was being pumped at 13 gpm. The vertical head difference observed in these two wells at the end of the test was 106.5 feet, and their distance from each other is 223 feet. Therefore, the temporary gradient developed within one hundred feet of the pumping well is on the order of 0.48 ft/ft, which is indicative of low permeability material equivalent to silty clay. Materials that create such steep hydraulic gradients generally do not comprise typical water supply aquifers. Wells constructed in silty clay usually produce no more than a few gallons per minute.   The fact that NSH-007 was able to produce 13 gpm and actually develop a sustainable cone of depression indicates that water contributing to its yield must have been drawn from fractures rather than the rock mass in the vicinity of NSH-008.

Of the 27 tested wells, three were completed in the basin fill. The remained of the NSH wells were sealed off from the basin fill by grout and oversize casing and were completed in the bedrock. As such, a double porosity fractured rock model was used to analyze hydraulic conductivity and storage properties for these bedrock wells. The default analysis was based on a horizontal slab model, developed by Moench (1984). In this model, the fracturing is assumed to be uniform as illustrated by the sketch in Figure 3.

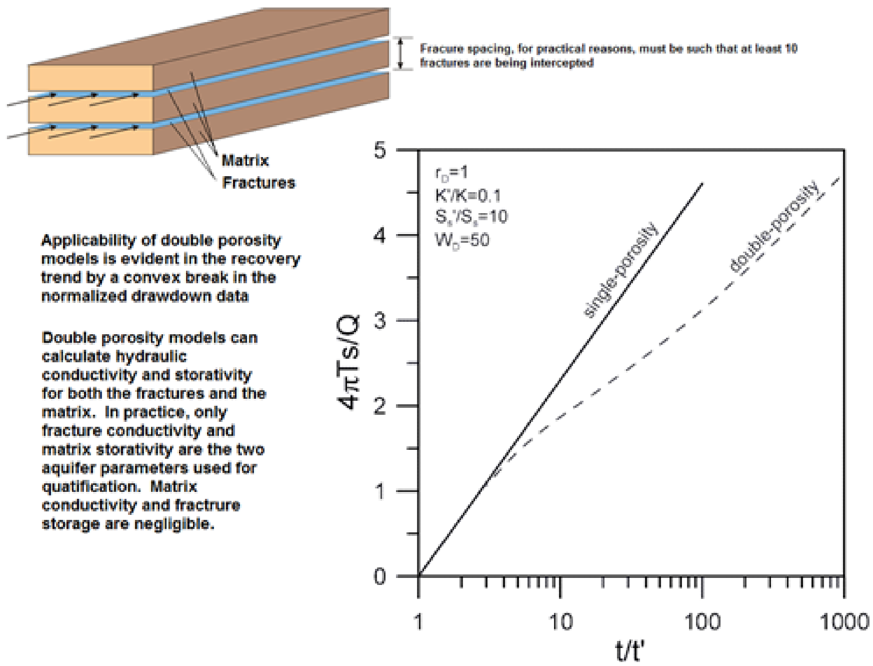
Figure 3. Two dual porosity scenarios of rock fracturing: horizontal slabs and uniform cubes



Moench (1984) solution model estimates hydraulic conductivity for both matrix and fractures

Flow to a pumping well is facilitated through intersection of the well bore by fractures. Under deep and confined conditions, release of water from the matrix into the fractures feeds this flow. Figure 3a illustrates this concept and indication of it in the drawdown curve for a horizontal block model.

Figure 3a Dual porosity flow system and its manifestation in drawdown data in a horizontal slab model



The actual fracture spacing and fracture set orientation is insensitive to the resulting hydraulic parameters because of equivalence between flow rate and number of fractures. The same amount of water can be conveyed to a pumping well with the same drawdown effect with fewer fractures provided they have higher individual conductivities. Only when the number of intercepted fractures is extremely high or low, will the drawdown relationship deviate from the linear flow model. If an infinitely large number of fractures is encountered by the well, the solution model becomes the porous medium equation developed by Theis (1935). On the other extreme, if only a single fracture is intercepted by the well, the drawdown pattern will reflect a fixed head boundary effect and will not represent linear flow to a well. Neuman (1987) has demonstrated for a fractured rock aquifer in Arizona, that a minimum of 10 fractures must be intercepted to derive a representative conductivity as a quantity defined over a continuum. Review of rock core from the Gunnison site indicate that more than 10 fractures occur in boreholes drilled to target depths ranging from 500 to 1200 feet.

2.3 Assumptions

Aside from the assumption of multiple (>10) parallel fractures intercepted by each of the tested wells, the Moench model also assumes the following:

- aquifer is confined with double porosity
- water is released instantaneously from storage with decline of hydraulic head
- aquifer has infinite areal extent
- aquifer has uniform thickness
- pumping and observation wells are fully or partially penetrating
- flow is unsteady

The first two assumptions regarding confined flow and instantaneous release are evident from the field data. In fractured rock aquifers, water moves in conduits resembling full pipe flow rather than in an unconfined system where pore water is replaced by air. In a confined system, water removal is matched by pressure re-distribution and depressurization of pores without the necessity of air entry. A confined system is recognizable by rapid propagation of pressure drop, analogous to a pipeline. It also is manifested by signal propagation over long distances. The bedrock aquifer tests from the Gunnison site conform to the confined character through virtually instantaneous onset of drawdown in all observation wells surrounding the pumped well, by the large distances (~700 feet) over which the pumping signal propagates, even with moderate pumping (10 – 30 gpm), and foremost, by the calculated storativities that are below 10^{-6} (unit-less). When storativity, defined as aquifer thickness times the specific storage, is below 5×10^{-5} groundwater is being released from matrix pores which remain confined (Todd, 1980).

The distances over which drawdowns propagate at the Gunnison Copper project site are shown in Figure 31 through 54, where each pumping well is shown with its accompanying observation wells.

The assumptions of areal extent and uniform thickness are necessary to derive analytical solutions for a drawdown model. While each aquifer will have a finite extent, the implication of these two assumptions is being diminished due to the time scale of the test (typically 5 days at Gunnison). It is likely that on that time scale, the effects of aquifer boundaries will not severely affect the drawdown curves since the volume of the aquifer is on the order of a cubic mile while the pumping effects are measured in thousands of cubic feet.

2.4 Basin Fill Aquifer Tests

Summary Table - Basin fill			
Tests	K (ft/d) min	K (ft/d) max	K (ft/d) mod
3	0.12	45	2

Three of the NSH wells are completed in the basin fill. These wells are NSH-006, NSH-011 and NSH-012. Tests in the basin fill proved to be difficult due to very limited saturated thickness. Only two of the basin fill wells could be tested and only one generated sufficient response from an observation well. Hydraulic conductivity estimates for the basin fill rely therefore in tests performed by others at neighboring parcels where the saturated thickness of the basin fill is greater. A hydraulic conductivity of 1.3 ft/day has been reported for the basin fill to the northeast of the Gunnison site (Summo Corp, 1998).

2.4.1 NSH-006

NSH-006 encountered only 33 feet of saturated basin fill before terminating at the top of bedrock at a depth of 684 feet. The limited saturated thickness precluded large pumping rates as the pump intake would dewater before the aquifer was sufficiently stressed. A test discharge rate of 3 gpm was therefore applied for a period of one day and water level observations were being made at five surrounding wells. The test was performed on December 11, 2012. The test well itself generated only 0.4 feet of drawdown which stabilized within 5 hours, indicating that good connectivity exists within the basin fill. However, from the five observation wells, which all were completed in bedrock, only NSH-005 registered a clear response from NSH-006 pumping. The distance between NSH-006 and NSH-005 is 208 feet. Based on this response, a transmissivity on the order of 900 $feet^2$/day can be estimated. The analysis for this well pair is shown in Figure 55. An unconfined drawdown model has been used in this analysis, corresponding to the conceptual understanding that the basin fill, when saturated, is open to the atmosphere. The recovery data from NSH-006 were analyzed with the Theis recovery model which yields a transmissivity of 2070 $feet^2$/day. The average transmissivity, when combined with a saturated thickness of 33 feet, yields a hydraulic conductivity value of K = 45 ft/d. Given the limited stress that could be generated by NSH-006 (low-flow pumping, 0.4 feet of drawdown), this value is not being considered as true representation of the conductivity in the basin fill.

2.4.2 NSH-011

This well is outside the mine area and its purpose is to test and monitor the saturated basin fill to the southeast of the site, in the potential flow direction of the regional groundwater. No nearby observation wells are available at this location. The primary purpose of well NSH-011 was to obtain accurate depth to bedrock and geophysical downhole logs to develop the geological model. The thickness of the saturated basin fill at NSH-011 is 52 feet. Because this well is designed as a 2-inch diameter monitor well, the testing took the form of a slug test, using a falling head test model to estimate the permeability of the basin fill at the contact with bedrock. The test took place on April 30, 2015. Two hundred gallons of locally-sourced groundwater were put into the well resulting in an initial head increase of 133 feet. Falling heads were monitored over the next 18 hours. The falling head data and associated analysis are shown in Figure 56. The results indicate a hydraulic conductivity in the basin fill of 0.15 ft/day. This is a low value when compared to the previous test and is more comparable to the hydraulic properties expected in the underlying bedrock. It is concluded that at this location, the bottom portion of the basin fill is cemented, which corresponds with the findings from the geophysical logs.

2.4.3 NSH-012 observation well

The borehole depth of NSH-012 is 504 feet and the well screen is set from 430 to 490 feet. The purpose of this well was to serve as an observation well for two deeper wells, NSH-010 and NSH-014B. However, after drilling and testing the deeper wells holes, it became evident that well NSH-012 is too shallow for the purpose of aquifer testing since it didn't intercept the regional groundwater table. The geophysical log from NSH-012 indicated that the base of the basin fill is highly compacted and transitions to the underlying white to cream colored massive crystalline marble of the Martin Formation. The Martin Formation was tested using other bedrock wells as described below.

2.5 Bedrock/ore body Aquifer Tests

Summary Table – Bedrock/Ore			
Tests pairs	K (ft/d) min	K (ft/d) max	K (ft/d) avg
62	0.01	9	1.1

The bedrock pumping tests were analyzed using the dual porosity models developed for fractured aquifer systems. Storativity and hydraulic conductivity are calculated separately for the fracture sets (denoted with K' and S_s' in the AQTESOLV figures) and for the unfractured rock (matrix), which are expressed as K and S_s in the AQTESOLV figures 55 through 105. Because the fractures are where flow and transport occur, the interpretation of dual porosity analyses as shown in Figure 3 focuses only on K and S_s', (fracture conductivity and matrix storage). Fracture storage (K') and matrix conductivity (S_s) are much less relevant to occurrence and transport and while they are calculated, they are not further used.

All of the bedrock pumping tests are analyzed with a confined aquifer model, which implies that water released from the formation into the bore is being replaced by depressurizing of the pores that are further away through re-adjustment of internal aquifer pressure. Depressurization of water in a confined aquifer is not accompanied by air entry. Instead, extracted volumes are matched by water expansion resulting from the reduced hydrostatic pressures in the aquifer (Driscoll, 1989). The Gunnison bedrock aquifer is interpreted as being confined because the data indicates this in three ways:

- propagation of signal over large distances (>1400 feet)
- instantaneous to rapid response to pump start in observation wells
- calculated storativities of less than 10^{-5} (dimensionless)

<u>2.5.1</u> NSH-001

North Star Hydrology well NSH-001 was tested on June 15, 2011 with a 2.5 hp pump yielding 30 gpm. Subsequent testing was performed on June 22, 2011 in form of a slug test in combination with spinner logging. The 30 gpm constant pumping rate test lasted 7 hours and culminated in a drawdown of 84 feet. The saturated column at the start of the test was 394 feet, suggesting that the aquifer was stressed by 84/394 = 21%, which is in the desired range from 15 to 25%. Figure 57 shows the resulting drawdown analysis based on the fractured rock slab model. The analysis suggests that the fracture sets in this bore have a hydraulic conductivity on the order of 0.17 ft/day, while the matrix conductivity is estimated at 0.05 ft/day. The storativity, defined as specific storage (units of ft $^{-1}$) multiplied by the hydraulic interval (394 feet) is $0.9 \cdot 10^{-6}$, is indicative of confining conditions.

NSD-011 served as observation well to the pumping test performed on NSH-001. The response recorded in NSD-011 is shown in Figure 58. Distance between the pumping well and the observation well is 73 feet. The maximum response to pumping at that distance observed in NSD-011 was 31 feet. Of interest is the flatness of the observed drawdown curve, suggesting that a steady-state condition is achieved. The applied analytical model cannot exactly match this condition, but with the best fit, the analysis for the conductivity between NSH-001 and NSD-011 yields a value of 0.1 ft/day, which is comparable to the single well analysis.

<u>2.5.2</u> NSH-002

Well NSH-002 is located in the southern part of the ore deposit and its location was selected based on inferred structural intersect on the Mojave #2 and Great Sandy Faults. High pumping yields were therefore expected and realized in this well during the pumping test performed on July 14, 2012. This well was pumped at 44 gpm and very quickly produced a drawdown of 58 feet. This drawdown remained unchanged for the duration of the test. Because of the unusual shape of the drawdown curve in the pumping well, hydraulic analysis is focused on the drawdown trends reported at two monitoring points: NSD-006 and NSD-014. These wells are 306 feet and 390 feet away from the pumped well. The maximum reported responses were 1.0 and 1.5 feet of drawdown at NSD-006 and NSD-014, respectively. This indicates that the more remote well (NSD-014) is actually in better hydraulic connection than the near well NSD-006. This behavior of larger drawdown being reported by a more distant well supports the use fractured aquifer analysis rather than a radial flow model.

The analysis of the NSH-002 and NSD-006 well pair is presented in Figure 59, yielding a hydraulic conductivity for the fracture set of 0.13 ft/day and a specific storage of $5 \cdot 10^{-7}$ ft^{-1}. Noteworthy is the fluctuation in the water level from this observation well which displays fluctuations attributable to earth tides. Earth tides are most evident in confined aquifer systems because in aquifers that are open to the atmosphere, air compressibility absorbs the pressure change. The fact that Earth tides are seen is further evidence that the groundwater at Gunnison is confined. Figure 60 shows the analysis from well NSD-014, showing a hydraulic conductivity of 1.6 ft/day. This well is located on top of the Mojave #2 fault which explains the higher hydraulic conductivity. The storativity is on the same order of magnitude as the previous test.

2.5.3 NSH-003

NSH-003 was tested on December 13, 2012 with a flow rate of 8 gpm for a period of 6 hours. Similar to the previous test, a steady drawdown was achieved in the first 20 minutes and maintained for the remainder of the test. The maximum drawdown achieved was 182 feet. None of the six observation wells registered any signal to the pumping from NSH-003. This limits the analysis to the pumped well only and yields a hydraulic conductivity for the fracture set of 0.05 ft^2/d, which is in general agreement with the K from the recovery stage transmissivity of 16 ft^2/d and a hydraulic interval of 180 feet. ($K_{recovery}$ = 16/180 = 0.09 ft/d). Because of the single-well limitation, little weight should be given to the storativity value determined for the NSH-003, but is assumed to be very low. The pumping test data analysis for NSH-003 drawdown is shown in Figure 61.

2.5.4 NSH-004B

NSH-004B was tested at a constant rate of 15.6 gpm for a period of 5 days, from November 9 to December 4, 2012. Maximum drawdown attained at this rate was 140 feet and a response was recorded in all eight observation wells. The nearest observation well to pumping was NSD-011 at 91 feet away. The maximum drawdown recorded there was 7.7 feet and its analysis is shown in Figure 62. The drawdown curve has been analyzed with the fractured rock horizontal slab model by Moench (1984) and yields a good match for the fracture set conductivity of 0.05 ft/day for the NSH-004B and NSD-011 well pair and a specific storage of $2 \cdot 10^{-7}$ (ft^{-1}). The next highest drawdown of 5.9 feet was observed in well CS-5, which is at a distance of 256 feet from the pumping. The analysis for this well pair is shown in Figure 63, resulting in a fracture conductivity of 0.3 ft/day and a similar storativity to that calculated with drawdown observations made at NSD-011.

2.5.5 NSH-005

NSH-005 was tested at a constant rate of 36.3 gpm for a period of 5 days from November 14-19, 2012. The maximum drawdown, 57 feet, developed at this pumping rate at the end of the pumping period. Most of the drawdown developed in the first five minutes of pumping with the remainder of the drawdown progressing very gradually. This typifies a fractured aquifer setting (Todd, 1980) and agrees with placement of this well at the intersection of two bedrock structures, the Atacama and the Forty Mile faults. One of the eight observation wells, NSH-006, shares the Forty Mile fault structure with the pumped well and its response is provided in Figure 64. The derived hydraulic conductivity of the fracturing between NSH-005 and NSH-006 is 4 ft/day with a spacing of these two wells of 208 feet. The estimated specific storage is on the order of 10^{-9} (ft^{-1}), consistent with the confined condition of this fracture system. Observation well NSM-001 which is located on a parallel structure Mojave #2 fault, registered a similar amount of drawdown at 496 feet distance away from the pumping well. The derived hydraulic conductivity between NSH-005 and NSM-001 is 1.3 feet/day, and suggests that crosslinking between the two parallel structures exist, most likely associated with the East-West oriented Atacama fault. Analysis of this response was analyzed with the same fractured rock slab model and is shown in Figure 65. Noteworthy is the absence of drawdown responses in wells NSD-011 and NSH-004B, which are within 300 feet of the pumped well and thus closer than NSM-001. It is concluded that these observation wells missed the fracture system of the Forty Mile, Atacama and Mojave #2 fault and thus display hydraulic no connectivity with NSH-005. Where the NSH-004B test displayed "tight fracture" responses at K of 0.3 ft/day, it is essentially surrounded by responses from the NSH-005 test which displayed "open fracture" responses with K values from 1.3 to 4 ft/day. Both of these K values are still orders of magnitude higher that the K values derived for the unfractured rock (matrix), K-prime, (K') at 10^{-5} ft/day.

2.5.6 NSH-007

Test well NSH-007 was pumped at 13 gpm for a duration of five days starting on December 21, 2015. It is surrounded by five observation wells that all exhibited a response. Maximum drawdown at the pumping well was 168 feet; the nearest observation well, NSH-008, registered a drawdown of 62 feet at 223 feet distance. The smallest response of 2.9 feet was recorded in NSD-026 which is 423 feet away from the pumping well. A very good match is obtained from the drawdown analysis using the Moench (1984) dual porosity slab model, yielding a hydraulic conductivity K of 0.07 ft/day between NSH-007 and NSH-008, Figure 66. Very similar values came out of the analysis and between the pumping well and NSD-028 and NSD-032 (Figure 67 and Figure 68). The average specific storage for this pumping test is $6.7 \cdot 10^{-7}$ ft^{-1}, while the matrix conductivity is $1.6 \cdot 10^{-5}$ ft/day, comparable to that from the NSH-005 test.

2.5.7 NSH-008

Following the step-drawdown test, NSH-008 was tested at a constant rate of 8.4 gpm for a period of 5 days from January 13-18, 2015. The relatively low pumping rate resulted in a drawdown of 175 feet at the pumped well and a drawdown of 40 feet in NSH-007 which is 223 feet away. The drawdown analysis for NSH-008 is shown in Figure 69; that of NSH-007 while NSH-008 pumping is shown in Figure 70. A good match is obtained for well pair NSH-008 and NSD-032, yielding a fracture set conductivity of 0.03 ft/day (Figure 71).

Of interest is the difference in onset of drawdown flattening between Figures 66 and 69. Under ideal conditions, the responses between NSH-008 and NSH-007, regardless of which is being pumped and which is used as an observation well, should be identical. In this case, NSH-007 was pumped harder than NSH-008, and therefore the drawdown curves differ in the amount of attained drawdown. The flattening, associated with full development of an extended well flow field, occurs sooner at NSH-008 (0.5 day), while in NSH-007 it occurs after one day of pumping. This is attributed to the distance to the Little Sandy fault, the nearest structural feature to both of these wells. This fault is acting as an impervious barrier, and while NSH-007 pumped more than NSH-008, it is further from this barrier such that its cone of depression develops over longer period of time. Similarly to the NSH-007 test, the specific storage of the unfractured rock deduced from this test is very low, $2{\cdot}10^{-6}$, ft $^{-1}$.

2.5.8 NSH-009

Test well NSH-009 was pumped at 6 gpm for a duration of five days staring on March 7, 2015. The maximum drawdown was 252 feet. Six surrounding wells served for observation of drawdown. Only two of these showed a response to pumping form NSH-009. The nearest of the two, NSD-037 responded with a drawdown of 89 feet, while NSH-008 at 763 feet away, dropped 6.2 feet. Interestingly, two wells, NSD-031 and NSD-032 that are closer to the pumping well but are completed to the north of the Little Sandy Fault, did not have any drawdown. Based on the amount of drawdown at a relatively low rate indicates low hydraulic conductivity. In the pumped well, the best drawdown analysis is achieved when a single horizontal fracture is assumed, as represented in the Gringarten-Ramey model. This analysis is shown in Figure 72 with an estimated hydraulic conductivity 0.005 ft/day and a matrix specific storage of $5{\cdot}10^{-10}$ ft^{-1}. These values are consistent with those calculated for observation well NSD-037 at K = 0.007 ft/day, shown in Figure 73. For the analysis of the NSD-037 response to NSH-009 pumping, a fracture spacing of 100 feet was used to optimize the curve match. This amounts to eight horizontal fractures through the 850 feet of saturated rock. Specific storage in the unfractured matrix is calculated at $4{\cdot}10^{-6}$, ft $^{-1}$.

2.5.9 NSH-010

NSH-010 was tested at a constant rate of 4 gpm for one day on April 21, 2015. The maximum drawdown at the end of the pumping period was 50 feet. A clear drawdown response of over 6 feet was registered in NSD-032, which is 312 feet distant from the pumping well. The hydraulic conductivity for NSH-010 drawdown data sets is calculated as 0.023 ft/day for a single well and as 0.034 for the NSH-010 to NSD-032 well pair, showing good agreement. The NSH-010 analysis is shown in Figure 74 and NSD-032 analysis is shown in Figure 75.

2.5.10 NSH-011

See Basin Fill aquifer test, section 2.3.2

2.5.11 NSH-012

Dry basin fill well

2.5.12 NSH-013

The NSH-013 test was started on April 29, 2015 and lasted five days with a flow rate of 10 gpm. Responses were monitored in five neighboring observation wells. Of these five wells, four registered a drawdown of less than one foot while NSM-007 responded with a 44 foot drop. The maximum drawdown in NSH-013 was 122 feet. The resulting hydraulic conductivity for this pumping-and-observation well pair is 0.04 ft/day (Figure 76). The estimated specific storage for the same well pair indicates strong confining conditions with S_s' of $1{\cdot}10^{-8}$, ft $^{-1}$. The confining conditions in this test are reinforced by the recovery analysis using the Theis residual drawdown solution, also valid for a confined aquifer, which yields a transmissivity for the pumped well of 17 ft^2/day. For a saturated aquifer thickness of 415 feet, this transmissivity corresponds to a hydraulic conductivity K of 17/415 = 0.04 ft/day, which is the same as calculated for the drawdown test.

2.5.13 NSH-015

This well proved to be a very high yielding well during well development. During testing, it was pumped up to 85 gpm from March 25-30, 2015. All nine surrounding observation wells showed a response, up to half a mile away. The explanation is that this well fully taps the Black Rock fault, a known conductive structure running along the western edge of the site. During pumping, this well attained a maximum drawdown of 76 feet. A single fracture model proved to yield the best fit for observation wells NHS-019 and NSD-019. These wells, while over 600 and 700 feet away from the pumping well appear to be sharing connectivity with the Black Rock fault system. The matches for these two wells (Figures 78 and 79), show a fracture conductivity based on the Gringarten-Witherspoon solution of 0.7 and 0.5 ft/day, respectively.

Observation wells that are closer to the pumping well but do not coincide with the structural alignment are better matched with the horizontal slab model. Two of these analyses are illustrated in Figures 80 and 81, showing the responses recorded in NSH-016 and J-05, yielding a hydraulic conductivity for the fracture set of 0.8 and 0.5 ft/day, respectively. Specific storage values from this test were the highest thus far with S_s' values from of $1.5\cdot10^{-4}$ ft $^{-1}$ to $7\cdot10^{-7}$, ft $^{-1}$, but still in the confined aquifer range. The test pumping rate from NSH-015 is equal to the one envisioned for a general recovery pumping well during the proposed mining operation. This test illustrates that even with a relatively low conductivity in the range from 0.5 to 0.8 ft/day, an area of influence with a radius of more than 500 feet can be developed. It also illustrates that extraction wells placed on a 100-foot grid are likely to strike the same fracture as a delivery well. The testing at NSH-015 showed that two out of nine observation wells struck the same fracture as the pumping well while being in a random pattern surrounding well NSH-015.

2.5.14 NSH-016

NSH-016 test was started on May 14, 2015 and lasted one day with an ultimate flow rate of 15 gpm. Its response was monitored in five neighboring observation wells. The pumped well developed a maximum drawdown of 60 feet, and the observation wells responded by less than 0.5 feet. Analysis of the drawdown in the pumped well is shown in Figure 82 and yields a hydraulic conductivity K of 0.4 ft/day. The construction of this well is similar to that of NSH-015, but because this well is located further west, it intercepts the Black Rock fault at a greater depth. The observation wells used in this test are all penetrating over 1000 feet deeper than the pumping well, which explains why the recorded signal is weaker in NSH-016 than in NSH-015, although the same structure is being tapped by both wells. The water level trends from NSD-002 and NSH-017 show clear evidence of Earth tides, which is characteristic of confined fractured groundwater systems. An oscillation with a 12-hour recurrence period is discernible in the hydrographs, superimposed on to the trend associated with one day of pumping and reaching maximum drawdown of 0.4 feet, shown in Figure 83.

2.5.15 NSH-017

Well NSH-017 is the highest yielding well tested during Gunnison Project hydrogeologic investigations. It was pumped at a maximum rate of 170 gpm from April 7-12, 2015. The maximum drawdown developed in the pumping well was 154 feet. Drawdown in excess of 12 feet was observed at a distance of 736 ft.

Seven observation wells registered the drawdown and provide solid basis for the analysis of hydraulic properties. The hydraulic interval of this well is located in between the Black Rock fault and the parallel Sonora Fault. It is screened at depth from 1010 to 1131 feet, making it 800 feet deeper than the two previous test wells, NSH-015 and NSH-016. The best response and speediest recovery is observed in monitoring well J-05, which is located 626 feet away from the pumping well. Figure 84 show the match for a fracture system with a hydraulic conductivity of 1.3 ft/day and a matrix specific storage of $4{\cdot}10^{-4}$ ft^{-1}.

Analysis of drawdown data from well NSH-015 is shown in Figure 85. The hydraulic conductivity in the direction to the pumping well is 1 ft/day, very similar to the previous well pair, and the specific storage is slightly lower, at $3.4{\cdot}10^{-6}$ ft^{-1}. The straight line segment from 0.5 day onward suggests bilinear flow, suggesting the main fault which NSH-017 intercepts, is receiving contribution from both sides of the fault plane in form of parallel flow lines, as opposed to radial, convergent, flow. The response in observation well NSH-016, which is on the edge of this fault zone, is predominantly radial flow. This suggests a wide fracture zone associated with the Black Rock fault, at least 300 feet wide, which is the transverse distance between NSH-017 and NSH-016. The analysis of NSH-016 drawdown caused by NSH-017 pumping is shown in Figure 86.

<u>2.5.16</u> NSH-018

NSH-018 testing started on April 12, 2015 and lasted five days with ultimate flow rate of 32 gpm. Its response was monitored in four observation wells; only three of them responded to the pumping with drawdowns on the order of one foot. Maximum drawdown attained in the pumped well NSH-018 was five feet, suggesting this well can yield higher rates that those used in the test. This well is located 1000 feet to the east of the ore body. Borehole data from this area do not show the intensive fracturing as observed in cores from within the ore body. Instead, the yield from this well is likely originating from a thin, altered bedding plane horizon between the marble at a depth of 920 feet in the Horquilla Formation, identified by geophysical logging, mineralogical assays, and drill cuttings.

Aquifer test data of NSH-018 is best analyzed with the confined Theis solution (Figure 87). The Theis solution determines the transmissivity (T) for the saturated portion of the aquifer assuming a fully penetrating well. The hydraulic conductivity is then calculated by dividing the transmissivity by the thickness of the aquifer, in this case yielding a K of 6.9 ft/day. The nearest observation well, NSH-020, which is at a distance of 162 feet, responded with one foot of drawdown. Since this well is much deeper than the pumping well NSH-018, a partially penetrating model solution has to be used to analyze the data. For this case, the partially penetrating well solution by Babu and Dougherty (1984) has been used and the resulting transmissivity is 3000 ft^2/day, which is in good agreement with the Theis analysis from the pumped test, shown in Figure 88.

<u>2.5.17</u> NSH-019

The pumping test at NSH-019 was started on March 12, 2015 and lasted 5 days. The pumping rate at the end of the test was 139 gpm. The maximum drawdown observed was 192 feet, while ten observation wells recorded associated drawdowns on the order of tens of feet. The response analysis for the pumping well is shown in Figure 89 with a K of 0.4 ft/day, while three observations wells, shown in Figures 90, 91 and 92 are in general agreement with a K value between 0.8 to 1.1 ft/day. The drawdown response in this well appears to propagate evenly in all directions. Therefore, the dual porosity model where by the fracturing is in two orthogonal directions (horizontal and vertical) as described by Moench (1984) was used for the analysis. This is consistent with NSH-019's location between two faults, Mojave #1 and #2 that is likely responsible for the crisscross fracturing. The lowest specific storage estimated for the rock matrix is $1 \cdot 10^{-5}$ ft $^{-1}$, in agreement the confined character of this fractured rock aquifer.

2.5.18 NSH-020

Testing of well NSH-020 took place from March 23-28, 2015 and ended with a steady pump rate of 32 gpm. The maximum drawdown in the pumped well was 10.4 feet. This test can be regarded as a reversal in flow direction when NSH-018 was being tested, also at a rate of 32 gpm, and in which NSH-020 served as an observation well. The drawdown analysis for this test was similarly performed with the Theis confined aquifer model. The drawdown in the observation well is slightly smaller than during the reversed role test: 0.8 feet versus 1.0 feet. The analysis yields a comparable transmissivity of 4626 ft^2/day, corresponding with a K value of 4.7 ft/day. The specific storage estimated from this test is $2.8 \cdot 10^{-7}$ft $^{-1}$. Aquifer parameter values are shown for the NHS-018 response in Figure 93.

Well pair NSH-020 and NSH-029 was also analyzed with the Theis confined aquifer model (Figure 94). It is unclear what happened with the water level in the observation well on day four of the test, but it evidently recorded an anomalous rise in water level that has not been explained. The first four days of the test data were analyzed by the partial penetration model by Babu and Dougherty (1984). A transmissivity of 1390 ft^2/day was calculated, which corresponds to a hydraulic conductivity of 1.8 ft/day. The data therefore indicate that both the thickness of the fractured rock aquifer and the permeability decrease in the southern direction across the NSH-018 to NSH-029 transect. The estimate of the ratio of horizontal (radial) to vertical conductivity (Kr/Kz) of 0.006 points to a strong vertical anisotropy that is expected in a banded limestone and marble rock system. Just as in NSH-018, the water bearing zone(s) appear to be controlled by bedding planes rather than sub-vertical fractures as seen in the ore body.

2.5.19 NSH-021

The testing on NSH-021C was performed in conjunction with spinner logging at NSH-019. The first stage of this combined “push-pull” test was pumping from NSH-021C while water level and flow was monitored with high recording frequency in NSH-019. Subsequent stages of the push-pull testing included two different injection rates. This analysis reflects the pumping only test for the well pair NSH-021C and NSH-019. The drawdown from the pumped well is shown in Figure 95. The pumping was briefly interrupted for technical reasons 3 hours into the test. Despite this brief interruption, a good match between observed and simulated drawdown is achieved when the fractured rock slab model is used. The fracture set conductivity is estimated at 0.13 ft/day. The relatively high conductivity of the rock matrix is estimated for this site at 0.009 ft/day. This is consistent with the location of well NSH-021C in close proximity to the Mojave #1 fault where fracturing is expected to be pronounced.

2.5.20 NSH-022

Well NSH-022 was drilled to verify the conductivity in the transition zone at the bottom of the oxide ore body. The well is screened from 1010 to 1131 feet depth over a length of 121 feet. Testing was performed on April 3, 2015 and lasted only 2.5 hours by which time a drawdown on 275 feet was observed. No further pumping was possible with the given pump size and intake depth setting. This response is indicative of very low hydraulic conductivity, and the proportion of well bore storage is too large for matching analysis. A straight line analysis as described by Cooper-Jacob was applied, and yielded a transmissivity estimate of 0.4 ft^2/d, as shown in Figure 96. Assuming the screen length corresponds with the hydraulic interval, the estimated hydraulic conductivity at this location and depth is 0.4/121 = 0.003 ft/day.

2.5.21 NSH-023

Well NSH-023 proved to be another low conductivity bore, but capable of sustaining 20 gpm pumping rate. It was tested for five days starting on February 26, 2015 and was pumped at a maximum rate of 20 gpm. Only three steps of the initially scheduled four-step drawdown test were achieved. The drawdown reached 222 feet and came too close to the pump intake to proceed with pumping rates above 20 gpm. Nevertheless, a good analytical match was obtained from the pumped well alone (Figure 98). The estimated hydraulic conductivity for this location is 0.07 ft/day. Analysis of the same test at surrounding observation wells yields a slightly higher hydraulic conductivity: K = 0.25 ft/day in the response at NSH-004B (Figure 99), K = 0.3 ft/day at NSH-025 (Figure 100), and K = 0.37 ft/day at NSH-001 (Figure 101).

2.5.22 NSH-024

NSH-024 testing started on May 26, 2015 and lasted one day with a final flow rate of 30 gpm. Responses were monitored in eight observation wells; they all responded with drawdowns from one to 15 feet. The pumping rate was scheduled to go to 35 gpm, however the drawdown became excessive. Therefore, after eight hours into the test, the pumping rate was reduced to 30 gpm upon which the drawdown stabilized near 226 feet. The analysis from the pumped well is shown in Figure 102 resulted in a hydraulic conductivity of 0.06 ft/day.

Hydraulic conductivities ranging over one order of magnitude are estimated from the drawdown responses at the observation wells. The lowest conductivity was calculated for the well pair NSH-024 to NSH-025. These wells are only 142 feet apart and the depths of completion are the same, but NSH-025 missed the fracturing associated with the Mojave#1 fault system. The estimated hydraulic conductivity between this well pair is 0.03 ft/day (Figure 103).

The well pair NSH-024 and NSH-004B had the highest K from this test (Figure 104). While the distance between these two wells is 339 feet, the response to pumping in the observation well mimics that in the pumped well and is indicative of good hydraulic communication. A conductivity of 0.9 ft/day was calculated for this well pair.

The remainder of the observation wells have K values between 0.03 and 0.9 ft/day, and their responses are combined in Figure 105. The slopes of the drawdown trends have a warm color when low (high K) and a cold color when steep (low K). The figure shows that it is not necessarily the distance from the pumping well that determines drawdowns; the controlling factors appears to be the wells' positions in relation to the fault system that was intercepted by the pumping from NSH-024. Wells to the west of NSH-024 display good communication and gradual drawdowns (warm colors in Figure 105, for example NSM-008 and NSH-019). To the east, only wells that are very deep (>1100 feet) communicate well with the pumping well, such as NSH-004B. Others, including NSH-023 and NSH-025, show marginal interconnection at a distance of few hundred feet.

The recovery data from this test also reveal two types of responses in the observations wells: those with a low transmissivity T = 150 ft^2/d, and those with fast recovery and a T = 750 ft^2/d, matching the grouping determined by the drawdown analysis. The fast-responding wells suggest a specific storage of the Mojave#1 fault system to be on the order of $1 \cdot 10^{-8}$, ft^{-1}. The average storativity of the slow-responding wells (NSH-023, NSM-005A and NSH-023) is slightly higher at $7 \cdot 10^{-6}$ ft^{-1}.

<u>2.5.23</u> NSH-026

Well NSH-026 was pumped at a maximum rate of 67 gpm for a period of 5 days, starting on April 17, 2015. A drawdown of 165 feet was recorded at the end of the test. Pumping generated responses in five of seven observation wells. Two of these responses were more than one foot and are presented here. Observation well NSH-022, at a distance of 224 feet from the pumping well, had a maximum drawdown of 114 feet. Figure 107 shows a poor match of the observed to the simulated drawdown data, especially during the early stages of the test. Because discharge control could not be properly regulated at the pumping well due to pulsing, the initial pumping rate reached 110 gpm at four hours into the test, then it dropped down to 13 gpm for two hours before leveling at approximately 75 gpm for the remainder of the 5-day test. The early data (less than 0.5 days) of the test are therefore difficult to match.

Observation well NSH-004B is over 1200 feet away from NSH-026. It registered a very clear response to pumping from NSH-026 as shown in Figure 108. The connectivity around NSH-004B was known from previous tests and is attributed to the Mojave #2 Fault zone. Well NSH-026 is not in that fault zone, but its response suggest hydraulic connectivity with the splay surrounding this fault. The estimated hydraulic conductivity between NSH-026 and NSH-004B is estimated at 12.5 ft/day, the highest value determined for the Gunnison ore body. By being over 1200 feet distant from the pumping well, the hydraulic conductivity derived from this well pair is not representative for the surroundings of NSH-026 and it's K value has not been used in further work. It is included here to show the long-distance connectedness of the particular structure. The value for specific storage for this well pair, $3.9 \cdot 10^{-7}$ ft^{-1}, is in agreement with the values from other tests and is indicative of a confined system.

<u>2.5.24</u> NSH-027

Testing of well NSH-027 took place from March 18-23, 2015 and ended with a pumping rate of 60 gpm. The maximum drawdown in the pumped well was 165 feet. Pressure transducers were deployed in ten observation wells. The hydraulic conductivities range from 0.06 to 1 ft/day. The most remote well to show a clear response was NSM-005A with a drawdown of 23 feet at a distance of approximately 1200 feet. The conductivity between it and the pumping well is estimated at 0.1 ft/day (Figure 109). NSM-

009 is approximately half the distance away and yet it developed comparable drawdown of 29 feet. The reason for this similar drawdown at vastly different distance from the pumping well must be sought in the geometry of the well layout to relative to the fracture intercept. While NSM-009 and NSM-005A both intercept the Mojave#2 fault, the distance from the observation well to the fault is more for NSM-009 than for NSM-005A and therefore the analysis yields a lower conductivity of 0.06 ft/day for NSM-009 (Figure 110). This despite NSM-009 being closer to the pumping well in terms of well-to-well distance than NSM-005A.

Figure 111 shows the response recorded at NSD-022, and Figure 112 shows the response at NSD-012. This last well has a screened interval open to a depth of 1731 feet. A relatively high conductivity is interpreted as a response to the fracturing of the ore body at a relatively uniform frequency. In this pumping test, a correlation exists suggesting the deeper the bore, the more fractures are encountered.

2.5.25 NSH-028

Well NSH-028 was tested for four hours at a pumping rate of 2 gpm. Similarly to NSH-025, this borehole did not yield sufficient water to meet the minimum requirement for the test pump for the given lift. Within minutes of the start of pumping, the drawdown exceeded 100 feet. A very low transmissivity was expected and the result of the analysis (0.75 ft^2/day) is shown in Figure 113. The penetration depth of NSH-028 into the bedrock aquifer is 265 feet. Assuming all of it contributes to the hydraulic interval, the hydraulic conductivity is estimated as 0.003 ft/day. Based on the low conductivity, it appears this well missed the fracture zone. This is supported by the recovery analysis which also showed a very low transmissivity.

2.6 Sulfide Ore Pumping Tests

Summary Table – Sulfide ore			
Tests	K (ft/d) min	K (ft/d) max	K (ft/d) geomean
3	0.001	0.03	0.01

Two deep wells, NSH-014B and NSH-025 were driven fully through the oxide ore zone and screened below it in a zone where mineralization transitions from oxides to sulfides. Relatively short well screens were separated from the ore body by grout plugs. Reasoning for these two installation was to verify the permeability of this zone with regard to penetration of lixiviant into an ore where it is not effective for in-situ recovery.

2.6.1 NSH-014B

Well NSH-014B is completed below the oxide ore zone. The well is screened from 1180 to 1260 feet depth. Extreme drawdown of 442 feet resulted from pumping for 1.5 hours at 1 gpm. With effort, a hydraulic conductivity of 0.001 ft/day is estimated (Figure 77). Since the sulfide zone is not conductive, no fractured aquifer model was used for analysis of the data. Upon pump shutdown, the water level rebounded by only 167 feet. The five observation wells used for this pumping test are completed in the ore body. None responded to pumping from NSH-014B, suggesting a lack of connection between the oxide and sulfide zones.

2.6.2 NSH-025

The purpose of NSH-025 was to determine the hydraulic properties of the "sulfide ore", i.e. the zone below the oxide and transition zones. The screened interval of this well is from 1480 to 1551 feet depth. The discharge drawn from NSH-025 was very low and commenced on May 5, 2015. The test lasted three hours and even during this short period, the discharge rate had to be reduced from the initial 6 gpm to 3 gpm. Very rapid drawdown of over 200 feet occurred within minutes of pump start-up. Wellbore storage had to be subtracted from the calculations to discern the response attributed to formation water. Figure 106 shows the Moench analysis for this low-yielding well. The best match yields a transmissivity of 8.5 ft^2/day and a hydraulic conductivity of 0.03 ft/day.

2.7 Well Efficiencies

Summary Table – Well efficiency			
Tests	E_w (%) min	E_w (%) max	E_w (%) avg
8	36	100	84

In a step-drawdown test, the discharge rate in the pumping well is increased from a low constant rate through a sequence of pumping intervals (steps) of progressively higher rates. Each step is typically of equal duration, lasting from approximately 30 minutes to 4 hours. Each step should be of sufficient duration to allow dissipation of wellbore storage effects. The amount of pumping during each step is ideally distributed in four steps below and above the well's expected sustainable yield (Q_s) as $0.5 \cdot Q_s$, $0.75 \cdot Q_s$, Q_s and $1.25 \cdot Q_s$. Since each step generates an incrementally deeper drawdown, a well efficiency can be calculated according to the following formula:

$$E_{\mathrm{w}} = \frac{B_1\,(r_{\mathrm{w}},t)Q}{\Delta h_{\mathrm{w}}\,(t)} \times 100\%$$

Where E_w is well efficiency, B_1 is the aquifer loss, r_w is the well bore diameter, t is time since pumping began, and $h_w(t)$ is the drawdown in the pumped well. In essence, efficiency is the difference in water level inside the well screen and outside the well skin where formation damage may have occurred during drilling. In a well that is 100% efficient, the drawdown inside the well screen and outside the well skin are the same. Well efficiency also takes into account the effects of screened well completions when a screen is not facing a yielding horizon in stratified or fractured aquifers. (Kruseman and de Ridder, 1994).

2.7.1 NSH-015 step test

Figure 114 shows the step drawdown analysis of well NSH-015. A partial penetration confined aquifer model was applied based on the mathematical formulation by Dougherty and Babu (1984). The key assumption in this analysis is that water is released instantaneously from storage with decline of hydraulic head. The data illustrate a poor match in the first three steps of the test. This is likely due to difficult flowrate control and low rates from such a depth. Nevertheless, the final step does line up well with the solution model, analog to a Cooper-Jacob solution, and leads to an estimated transmissivity of

517 ft^2/day. Well efficiency calculated with the above formula is 100%. This well is not screened so that little or no losses are caused by well completion.

2.7.2 NSH-017 step test

Figure 115 shows the step drawdown analysis of well NSH-017. This high yield test demonstrated that rapid equilibrium can be reached during each step. This indicates that the fractures of the Black Rock fault system are extensive and very well-connected. This well has a hydraulic interval from a depth of 940 to 1181 feet, or 40% of the saturated zone. The calculated well efficiency is 100%, indicating that the well screen encompasses most, if not all the fracturing associated with this fault system. In subsequent quantifications, the length associated with the Black Rock fracture zone is therefore assumed to have a vertical scale of 200 to 240 feet (corresponding to screened intervals in the Black Rock fault) and a horizontal (spatial) scale of 250 to 300 feet. This agrees with the measured dip of the fault plane of 55° to the west as derived from structural analysis and assuming a linear projection. In reality, the Black Rock fault curves slightly to the west, but at NSH-017, the alignment of the fault can be assumed as being north-to-south.

2.7.3 NSH-018 step test

NSH-018 step-drawdown test is shown in Figure 116. A very good match is achieved with a confined Theis solution and the calculated well efficiency is 76%. The well completion of this well consists of 382 feet of screen in a saturated interval which is 401 feet thick. This would indicate that NSH-018 is only partially penetrating and that water is being pulled in from greater depth with aquifer losses being caused by radial convergence. The transmissivity of 3667 ft^2/d over the saturated interval yields a K value of 9.1 ft/d. If the full thickness of the hydraulic interval of 932 feet is used, this analysis results in a conductivity value of 4 ft/day.

2.7.4 NSH-019 step test

NSH-019 step-drawdown test is shown in Figure 117. This well is competed to a depth of 1410 feet, penetrating the full thickness of the oxide ore body. The calculated well efficiency for NSH-019 is 94%, suggesting good communication between the groundwater in the ore body and the well bore over its entire penetration depth. Since this well is not screened but fully completed in fractured rock, the efficiency refers to the aquifer and its capability to transmit water to a 192 foot deep cone of depression. The transmissivity derived for the step drawdown test is 264 ft^2/d. When divided by the hydraulic interval of 808 feet, it yields a K value of 0.3 ft/day, which is a good agreement with the values obtained from the individual drawdown analyses at seven observation wells with different completion depths, and used for drawdown observation during the NSH-019 constant rate pumping test. The result suggests that the ore zone is transmissive throughout the hydraulic interval.

2.7.5 NSH-020 step test

The step drawdown progression at NSH-10 is shown in Figure 118. In this analysis, the match is poor for steps 1 and 4 of the test. Step 1 was hampered by difficulty of maintaining a low flow rate from such a depth with a pump rated for much higher flows. Step 4 displays a gradual increase of drawdown only during the second day of pumping while leveling off from day three onward. This trend can be explained by dewatering of a shallow fracture set where by the inflow to the bore is later matched by an equal amount from a deeper fracture set that is only triggered after the shallow fractures are depleted. In a complex conduit network of fractures, a siphon effect can cause this type of response. Under normal circumstances, however, increase of pumping can only cause a progressive increase of drawdown response. Alternately, the apparent flattening of drawdown response can be the result of decreasing extraction flow rate which may have gone unnoticed by the field crew. The estimated well efficiency is 100%, noting that this well is fully penetrating.

2.7.6 NSH-023 step test

This test was comprised of three steps. Only minimal amount of water level data from step 1 could be collected due to unsteady conditions upon pump insertion into the bore. A confined step analysis has been applied to the data (Figure 119). The value for well efficiency derived from this test is 85%. The estimated transmissivity is T=26 ft^2/d, and is consistent with the recovery analysis from NSH-023 (T=39 ft^2/d) and the individual drawdown analyses obtained from observation wells engaged during the pumping testing at NSH-023.

2.7.7 NSH-024 step test

As with NSH-023, this test was comprised of only three steps. When the fourth step was initiated at 5 hours from the start of pumping, it became evident that 35 gpm was not sustainable. The flow rate was reduced to 30 gpm to allow the test to continue. This temporary bump on the drawdown curve can be seen in Figure 120 at time 300 minutes (5 hours) from pump start. This pumping regime is likely affecting the calculations because the efficiency values is based on the final two steps. This negative influence should is considered when interpreting a well efficiency value for NSH-024 of 36%.

2.7.8 NSH-027 step test

The analysis of the step drawdown test on NSH-027 is shown in Figure 121. A very good match between observed and simulated drawdown can be seen for all stages of this test. The transmissivity is calculated at 338 ft^2/d, which for the saturated thickness of 451 feet translates to a K = 0.75 ft/d. The fact that this well's bore is only screened from a depth of 865 to 1010 feet, indicates that more screened interval would yield more water because the water bearing zones are spread over the full submerged interval. As inferred from the drill logs, this well taps the sub-vertical Mojave#1 fault and is in good communication with the surrounding observation wells. The well efficiency of NSH-028 is calculated at 78%. The low transmissivity derived from the recovery test of 83 ft^2/d is considerably lower than what is derived from the pumping tests. In most pumping test settings, the recovery in a well yields a higher transmissivity value than the pumping phases of either the step or constant rate tests. The discrepancy is attributed to the very low storage (lack of water) rather than low conductivity. For an in-situ recovery scheme, this is a favorable condition which reduces the volumes needed for wellfield conditioning.

3. Packer testing

A total of nine wells were tested with packers to isolate discrete intervals of the boreholes. Two of the tests were performed on the hydrology boreholes and seven on cleared and developed core holes originally used for mineralogical sampling (NSD and NSM). Well NSH-001 was tested at four discrete depth intervals of 20 to 70 feet. Four target zones were selected and the following conductivity depth profile was generated, Table 2:

Table 2 Discrete depth conductivity tests at NSH-001

Well NSH-001	K (ft/day)
770-820 feet	0.12
860-930 feet	0.21
940-980 feet	0.22
1020-1040 feet	0.15
Aquifer Test	0.2

The packer testing in NSH-001 demonstrated that the permeable zones are evenly distributed throughout the oxide ore body and the values are in good agreement with the yield from the pumping test which does not differentiate from which depth the water is originating, but corresponds to the interval with the highest K.

Well NSH-020 was packer tested, and subsequently screened at three different intervals. The purpose of this was to discern three water yielding areas identified during drilling and subsequent caliper logging: a bedding plane at the base of the Horquilla Formation (Naco Group), a fault plane within the Escabrosa (Patagonia Fault), and the contact between the Escabrosa a Martin limestone beds. Pumping tests at these three intervals provided similar K values indicating that the rock formations to east of the site contain high-yield zones associated with structures (E-W faults and E-dipping beds) other than those found in the oxide ore body (NNW trending fault zones).

The final suite of packer testing, performed in June 2015, included boreholes NSM-006, -007, -008, -009, NSD-037 and NSD-043. While the purpose of these tests was to determine the strength of the rock with respect to injection under pressure by so called fracture gradient testing, the responses can be used to estimate K-distribution with depth. During the fracture gradient testing, water was injected into a packer interval of 6 feet length while pressure and flow was recorded. The flow increase was gradual, as opposed to stepped as under a standard Lugeon Test, but it was recorded on high enough frequency to allow plotting of five Pressure/Flow points to enable a quantification of hydraulic conductivity. A Lugeon unit (Lu) is the conductivity required for a flow rate of one liter per minute per meter of borehole interval under a constant pressure of 1 MPa (1MPa = 145 psi).

Data collected during the fracture gradient testing showed that a typical flow of 10 gpm through the packer interval required an injection pressure of 300 psi. These values translate to a conductivity of 9 Lu. Since 1 Lu equals approximately $1 \cdot 10^{-7}$ m/s, it can be deduced that the massive formations stressed during the fracture gradient testing have a hydraulic conductivity of up to 0.09 ft/day. This value is in agreement with pumping test data, where even the lowest yielding wells (NSH-003, NSH-009 and NSH-024), are able to recover 90% of their drawdown within three days, and despite the low conductivity are able to hydraulically communicate over several hundred feet. Little variation has been encountered in the fracture gradients with depth of the ore body, where up to seven intervals were tested in one borehole. This observation can be directly extrapolated to the variation of hydraulic conductivity with depth, which is assumed to be evenly distributed across the vertical dimension in the oxide ore.

4. Porosity

Summary Table – Porosity			
Tests	Porosity min	Porosity max	Porosity avg
3	1%	3.5%	3%

Estimates of porosity of the oxide ore body were made using three methods at different locations and scales. The most direct method is from a downhole geophysical logs using a focused density logging tool based on gamma ray scattering. The tool used at Gunnison was Mt. Sopris short-spaced detector. Once inserted into the borehole, a small radioactive source begins emitting Compton-scatter gamma rays that a reflected back to two detectors on the probe. The difference in response in the near and the far detector is directly proportional to the bulk density of the media in which the gamma rays are introduced and scattered. A use of dual detectors allows for compensation to correct for the irregularities of the borehole. Porosity is then derived from the compensated bulk density log for an assumed grain density of the rock and fluid density for the fluid occupying the pore spaces. Density logs have been run in seven boreholes, namely NSH-008, -009, -013, -015, -023, -026 and -028, and processed for porosity estimates using solid density of 2.83 g/cm^3 and fluid density of 1.00 g/cm^3. The average porosity from these bores in the oxide ore is 2.7%.

Acoustic logs were also used to derive a value of porosity. In this method, sonic pulses are generated by the tool in selected wavelength range and the intensity of their bounce is recorded. The sound pulses get distorted on wavelength and delayed in velocity, depending on the type of medium they travel though. Sound signals that travel through a formation with many voids will slow down the propagating wave further than when they travel through a low porosity rock. Correction is applied in the calculations to subtract the effects of the fluids in the borehole, assuming it consists of fresh water. The sonic log and depth-discretized interpretation was performed on borehole NSD-011 and yielded an estimate for porosity of 3.5%.

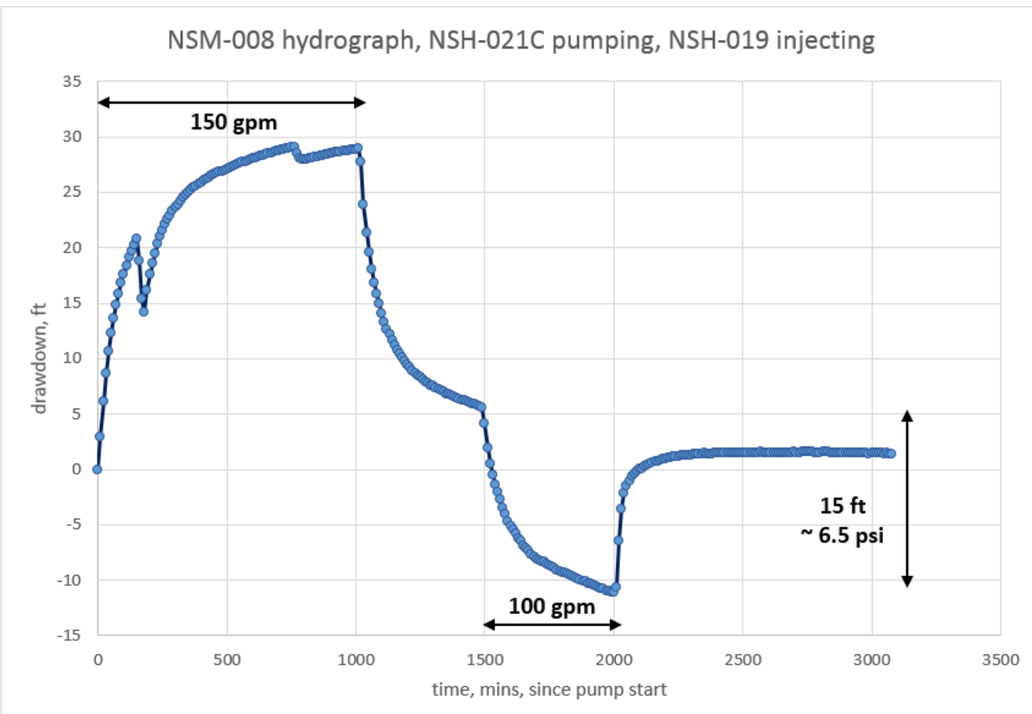
The final method for porosity estimates is measured at the field scale and relies on the assumption that the shape and volume of a cone of depression that develops during a prolonged pumping test is known. Porosity, by definition, is the ratio of the amount of water withdrawn during a pumping test divided by this volume. The methodology follows a USGS (1961) solution to determine specific yield from a pumping test. While this method was developed for unconfined aquifers, its simplicity serves well as a first estimate in calculation of porosity from extracted volume and area of contribution in a confined aquifer. Four wells tested during the hydrogeologic investigation had sufficient coverage by observation wells to estimate the extent of the cone of depression. These wells are NSH-017, -019, -021C and -024. During these tests, the amount of groundwater extracted ranged from 0.1 to 1 M gallons over the five days of pumping tests. The range of porosities estimated by this method is 1 to 2.5%. These values are slightly lower than the porosities obtained from the direct measurements, which is likely related to the unsteady-state of the developed cones of depression. Under ideal conditions, the water level in a pumping well is not changing while the water level changes in the observation wells are negligible. During the Gunnison tests, the water levels in the pumping wells after a five day pumping period were at, or close to a steady-state, however, the observation wells still reported a decline. This does not fully satisfy the method’s assumptions and therefore less weight is given to this approach of determining porosity.

1.0 Data Use

The collection of the hydraulic data described in the previous sections has multiple purposes. In the production process, the flow velocities between extraction and delivery wells will determine the plant through-put. For the average K-value from this investigation, 1.1 ft/day, it can be derived that the average travel time between extraction delivery well will be on the order of 19 days, based on a 100-foot by 100-foot grid spacing, unity gradient and a porosity of 3%.

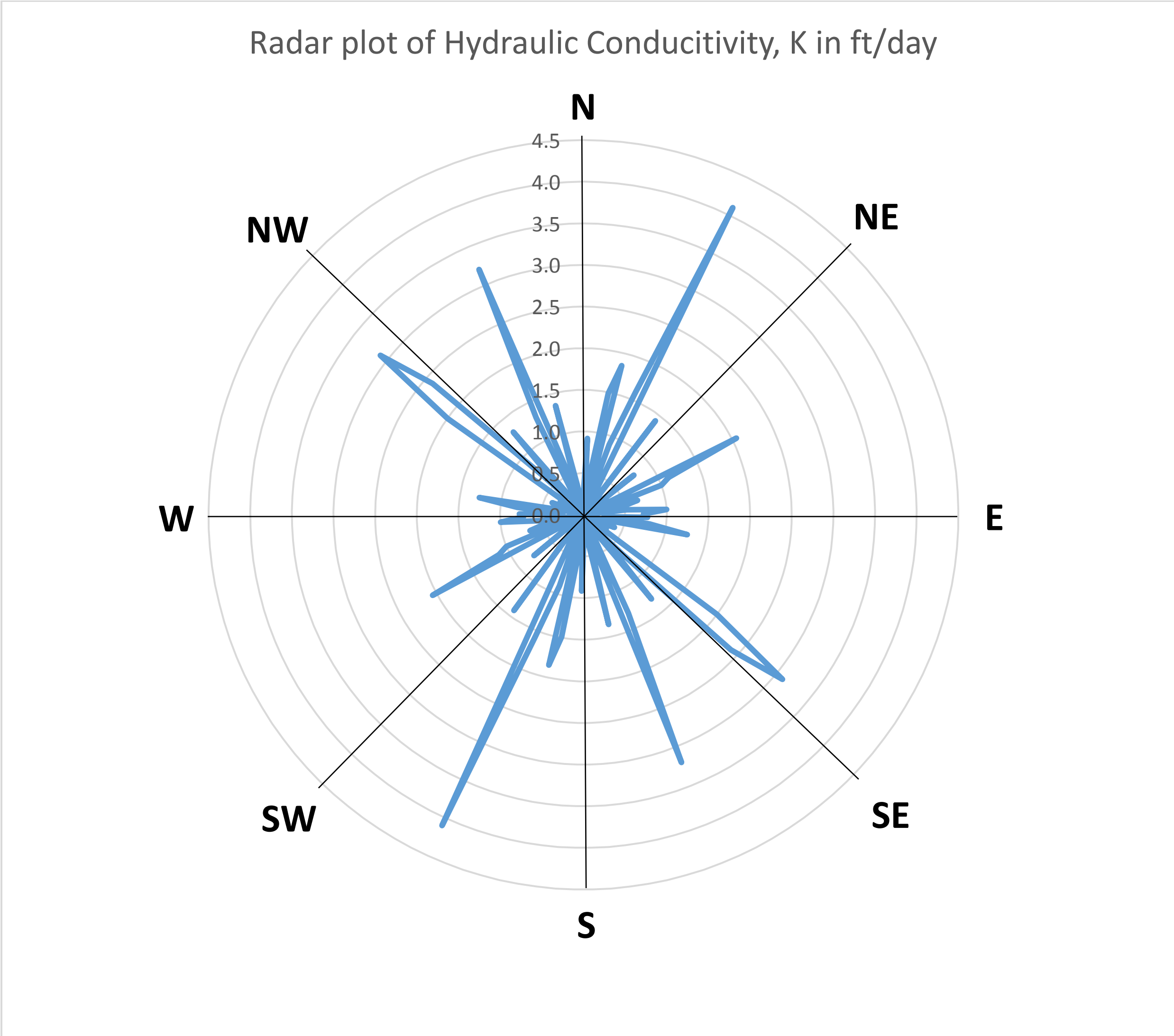
An observed response to pumping as well as injection at a monitoring point is shown in Figure 122. The hydrograph shows initial drawdown on the order to 30 feet in response to pumping at a distance of 143 feet from the observation. The same well then responds to injection into a well at a distance of 71 feet with a pressure mounding of 15 feet. This last separation distance corresponds to the projected spacing between recovery and delivery wells on a regular grid.

Figure 122. Hydrograph form well NSM-008 during push-pull simulation



The K data from this investigation lends itself for directional analysis. For each well pair (pumping well and observation well) where a hydraulic conductivity has been calculated, there is also an azimuth, or direction, between those wells. When plotted on a radar plot from 0 to 360°, a directional distribution of K value is generated (Figure 123). This figure, composed only for the well pairs within the oxide ore body, shows that the hydraulic conductivities are relatively evenly distributed with little prevalent direction, despite being controlled by linear fault systems. It is concluded that the faulting occurred in multiple phases and along different directional faulting axes such that a crisscross fracture pattern developed that intersect sufficiently enough at the well spacing of 100 feet to smooth out, for the purpose of hydraulics, discrete fracture spacing which is on the order of one foot.

Figure 123. Compilation of K-values from the Gunnison ore body by azimuth and magnitude

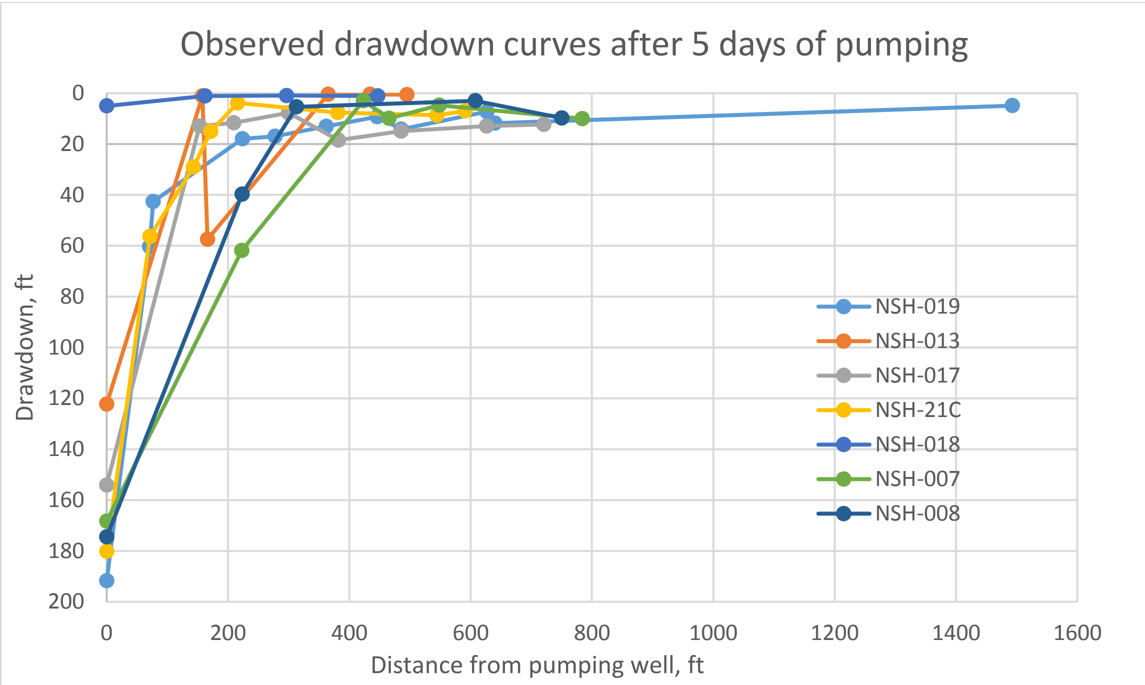


The hydraulic data from this investigation is also used to populate and calibrate the hydrogeological flow model (CCA, 2015). Use was made of the correlation between fracture intensity, as obtained from the core analysis, and the hydraulic conductivity determined from the pumped well recovery curves (Figures 4 to 29). Four of the pumping tests (NSH-015, -020, -024 and -027) were used in the transient calibration to match the observed drawdowns during the pumping tests with the simulated heads in different layers and geologic formations.

For the purpose of well spacing of hydraulic control wells, the results from the step-drawdown tests identified sustainable yields for the pumped wells, which are used to estimate the extent of capture zones. Matching observed and simulated drawdowns over distance from a pumping well is used to locate observation wells that demonstrate inward gradient during in-situ recovery operation. Figure 124 indicates that most drawdown will occur within 200 feet from a pumping well. A distance in excess of

500 feet, on the other hand, is not likely to generate a head difference in excess of 1 foot, required as a minimum to demonstrate gradient.

Figure 124. Extent of drawdown influence from seven 5-day tests, projected onto a cross-section.



5. Summary

The conceptual model applied to the Gunnison Copper Project site discerns two major hydrogeologic units:

- basin fill, partially saturated and overlying the next unit and
- fractured bedrock, where meaningful permeability only exists in fractures.

Fractured rock is further subdivided into highly fractured zone associated with skarn alteration (oxide ore body), and less fractured rock, corresponding with the sulfide ore deposit and the unaltered host rock.

The range of hydraulic conductivities determined at the site is from 0.01 to 9.8 ft/day, or three orders of magnitude. The hydraulic parameters, and the well-pairs from which these have been derived, are shown in Table 3, together with the method of analysis and the lithology encountered in the hydraulic interval.

The basin fill, for most part, is unsaturated. Where basin fill does contain water, there is a very limited saturated thickness, making aquifer testing problematic. Hydraulic conductivity estimates are therefore based on a limited number of on-site pumping tests. Data from the Johnson Camp area, where the saturated thickness is greater, indicate a hydraulic conductivity for the basin fill of 2.0 ft/day. This value is used in the hydrologic model and is designated as lower basin fill.

Table 3. Aquifer testing results form NSH-wells at the Gunnison Copper Project

Pumped Well	Obs well	T, ft^2/d	K, ft/d	S, 1/ft	Method	Lithology
NSH-001	NSH-001	31.5			Theis recovery	Martin/Abrigo
	NSH-001		0.17		Moench-slab	
NSH-002	NSH-002	2000			Theis recovery	Martin/Abrigo
	NSH-006		0.13	6.70E-04	Moench-slab	
	NSD-014		1.6	1.00E-03	Moench-slab	
NSH-003	NSH-003	48.1			Theis recovery	Abrigo
	NSH-003		0.05	4.00E-07	Moench-slab	
NSH-004B	NSH-004B	210			Theis recovery	Martin/Abrigo
	NSD-011		0.05	4.00E-04	Moench-slab	
	CS-05		0.32	8.10E-06	Moench-slab	
NSH-005	NSH-005	1245			Theis recovery	Martin/Abrigo
	NSH-006		4.07	2.30E-05	Moench-slab	
	NSM-001		1.3	2.10E-06	Moench-slab	
NSH-006	NSH-006	1985			Theis recovery	Basin Fill
NSH-007	NSH-007	64.5			Theis recovery	Abrigo
	NSH-008		0.07	1.00E-12	Moench-slab	
	NSD-028		0.07	3.50E-07	Moench-slab	
	NSD-032		0.07	1.33E-05	Moench-slab	
NSH-008	NSH-008	5			Theis recovery	Abrigo
	NSH-008		0.01	1.20E-02	Moench-slab	
	NSH-007		0.04	3.50E-10	Moench-slab	
	NSD-032		0.03	1.96E-06	Moench-slab	
NSH-009	NSH-009	2.4			Theis recovery	Abrigo
	NSH-009		0.005	5.20E-10	Gringarten	
	NSD-037		0.007	3.80E-06	Moench-slab	
NSH-010	NSH-010	9			Theis recovery	Martin
	NSH-010		0.023	8.74E-03	Moench-slab	
	NSH-032		0.034	3.06E-07	Moench-slab	
NSH-011	NSH-011		0.12		Hvorslev	Basin Fill/Naco
NSH-013	NSH-013	17.1			Theis recovery	Martin
	NSM-007		0.04	1.00E-08	Moench-slab	
NSH-014B	NSH-014B	10.7			Theis recovery	Abrigo
	NSH-014B		0.01	3.27E-05	Theis confined	
NSH-015	NSH-015	1009.7			Theis recovery	Quartz Monzonite/ Abrigo
	NSH-019		0.67	7.00E-06	Gringarten	
	NSD-019		0.45	7.14E-06	Gringarten	
	NSH-016		0.40	9.00E-05	Gringarten	
	J-05		0.53	1.60E-05	Moench-slab	

Pumped Well	Obs well	T, ft^2/d	K, ft/d	S, 1/ft	Method	Lithology
NSH-016	NSH-016	709.5			Theis recovery	Quartz Monzonite
	NSH-016		0.41	3.66E-03	Moench-slab	
	NSD-019		1.25		Theis recovery	
	NSH-017		0.95		Theis recovery	
NSH-017	NSH-017	913.2			Theis recovery	Abrigo
	J-05		1.3	4.00E-04	Moench-slab	
	NSH-015		1.0	3.40E-06	Moench-slab	
	NSH-016		0.77	1.00E-10	Moench-slab	
NSH-018	NSH-018	1995.2			Theis recovery	Naco
	NSH-018		7.0	2.46E-10	Theis confined	
	NSH-020		7.5	8.06E-07	Dougherty	
NSH-019	NSH-019	699.1			Theis recovery	Martin/Abrigo
	NSH-019		0.42	1.29E-07	Moench-cube	
	MSN-008		0.77	1.00E-05	Moench-cube	
	NSH-024		1.0	1.00E-07	Moench-cube	
	NSH-017		1.12	1.00E-10	Moench-cube	
NSH-020	NSH-020	3715.4			Theis recovery	Naco/ Escabrosa/ Martin
	NSH-018		9.8	2.87E-07	Theis confined	
	NSH-029		2.94	2.02E-08	Dougherty	
NSH-021C	NSH-021C	197.5			Theis recovery	Abrigo
	NSH-021C		0.13	1.00E-02	Moench-slab	
	NSH-024		1.0	1.00E-07	Moench-cube	
	NSH-024		0.63		Theis recovery	
NSH-022	NSH-022	1.8			Theis recovery	Martin/Abrigo
	NSH-022	0.4		8.50E-06	Cooper-Jacob	
NSH-023	NSH-023	39			Theis recovery	Martin/Abrigo
	NSH-023		0.072	1.00E-03	Moench-slab	
	NSH-004B		0.25	9.40E-02	Moench-slab	
	NSH-025		0.3	1.00E-07	Moench-slab	
	NSH-001		0.37	1.80E-09	Moench-slab	
NSH-024	NSH-024	72.8			Theis recovery	Martin/Abrigo
	NSH-024		0.062	1.00E-10	Moench-slab	
	NSH-025		0.033	2.00E-06	Moench-slab	
	NSH-004B		0.9	8.73E-08	Moench-slab	
	NSM-008		1.1		Theis recovery	
NSH-025	NSH-025	2.3			Theis recovery	Abrigo
	NSH-025		0.03	1.00E-14	Cooper-Jacob	
NSH-026	NSH-026	400			Theis recovery	Escabrosa/ Martin
	NSH-022		0.08	1.00E-10	Moench-slab	

Pumped Well	Obs well	T, ft^2/d	K, ft/d	S, 1/ft	Method	Lithology
NSH-027	NSH-027	82.5			Theis recovery	Abrigo
	NSM-005		0.1	4.00E-04	Moench-slab	
	NSM-009		0.05	1.00E-05	Moench-slab	
	NSD-022		0.11	1.00E-03	Moench-slab	
	NSD-012		0.36	1.00E-04	Moench-slab	
NSH-028	NSH-028	2.5			Theis recovery	Martin/Abrigo
	NSH-028	0.75		3.37E-04	Cooper-Jacob	
	NSH-027		0.22		Theis recovery	

The oxide ore body has an average hydraulic conductivity of 1.1 ft/day. Variation in conductivity is controlled by intensive faulting and associated heterogeneities. Analysis of drawdown data in the orebody indicates that most wells are, to some degree, connected to these faults that can be regarded as "extended wells" where flow fines are parallel rather than radial. This is consistent with the application of the horizontal slab solution which allows the derivation of fracture conductivity (K) and matrix storage (Ss'). Storage coefficients indicate that the aquifer is confined. Overall, the wells demonstrate good connectivity through propagation of significant drawdowns over distances of over 1000 feet, which is indicative of confined conditions. Pumping rates at individual test wells varied from 2 to 170 gpm. Even the low-yield wells demonstrated this long-distance hydraulic connectivity and their water levels recovered to 90% within five days, confirming an interconnectedness of individual fractures. Well efficiencies, calculated for wells tested at 30 gpm or more, have an average of 84% with the supplement attributed to well entry and converging flow losses.

The horizontal slab model used to simulate the drawdown in the oxide wells assumes an evenly distributed fracturing pattern. To verify the validity of this condition, a number of packer tests were conducted to evaluate K variation across the thickness of the ore body. Interval injection tests and spinner-packer tests at nine locations indicate that permeability is not limited to a single fracture but is distributed over the full well depth. Exceptions to this uniform fracture distribution scenario are seen at three of the major fault zones in the area: Black Rock Fault, Mojave #2 Fault, and Patagonia Fault. These fault zones are therefore carried over into the site's groundwater model as discrete K zones.

Two deep wells that are completed in the transition zone from the oxide to the sulfide ore show the lowest hydraulic conductivity of 0.01 ft/day for the site. This value has been applied to the Texas Canyon Monzonite (non-ore Granitoid) as well as the sulfide ore and basal schist. Testing data indicate that, unlike the oxide ore, the connectivity is poor and recovery of drawdown is incomplete. Storage coefficients from the two wells completed in the sulfide zone, NSH-014B and NSH-025, are two orders of magnitude lower than in the oxide ore wells, indicative of very strong confining conditions. Assuming some deep fractures penetrate the sulfide zone, the expected flow direction is upward because a higher confining pressure will drive a moving water particle upward.

6. References

Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., vol. 16, pp. 519-524.

Kruseman, G.P. and N.A. DeRidder, 1990. Analysis and Evaluation of Pumping Test Data (2nd ed.), Publication 47, Intern. Inst. for Land Reclamation and Improvement, Wageningen, the Netherlands, 370p.

Todd, D.K., 1980. Groundwater Hydrology, John Wiley & Sons, New York, 535p.

Moench, A.F., 1984. Double-porosity models for a fissured groundwater reservoir with fracture skin, Water Resources Research, vol. 20, no. 7, pp. 831-846.

Dougherty, D.E and D.K. Babu, 1984. Flow to a partially penetrating well in a double-porosity reservoir, Water Resources Research, vol. 20, no. 8, pp. 1116-1122.

Gringarten, A.C. and H.J. Ramey, 1974. Unsteady state pressure distributions created by a well with a single horizontal fracture, partial penetration or restricted entry, Soc. Petrol. Engrs. J., pp. 413-426.

Summo USA Corporation, 1998, Johnson Camp Water Supply, Report 1525A.981221, external due diligence investigation.

USGS, 1961. A Simple Method for Determining Specific Yield from Pumping Tests, Ground-Water Hydraulics paper 1536-C, Washington DC.

Avci, C.B,, Ciftci, E. and Sahin, U., 2010. Identification of Aquifer and Well Parameters from Step-Drawdown Tests. Hydrogeology Journal vol. 18, pp. 1591-1601.

Driscoll, F.G., 1989. Groundwater and Wells. 2nd Edition, Johnson Filtration Systems Inc, St. Paul, MN.

Neuman, S.P., 1988. Stochastic continuum representation of fractured rock permeability as an alternative to the REV and fracture network concepts. University of Arizona, Tucson, with support from U.S. Regulatory Commission, NRC-04-78-275 and NRC-04-86-123, reprinted in Groundwater flow and quality modelling, D. Reidel Publishing Company, the Netherlands.

Jenkins, D.N. and & J.K. Prentice, 1982. Theory for aquifer test analysis in fractured rock under linear (nonradial) flow conditions. Groundwater, Jan. – Feb. 1982 (20)1: pages 12 – 21.

FIGURES 4 to 29.

RESIDUAL DRAWDOWN RECOVERY

OF NSH WELLS

ANALYZED WITH AQTESOLV

Figure 4

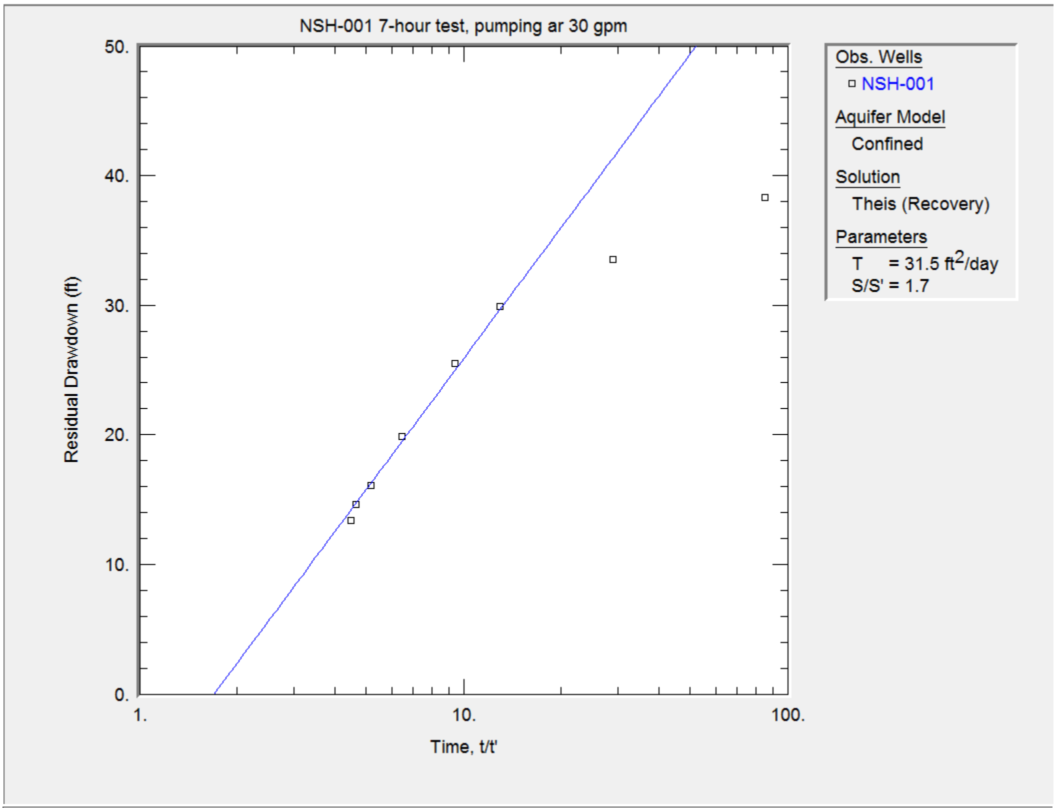


Figure 5

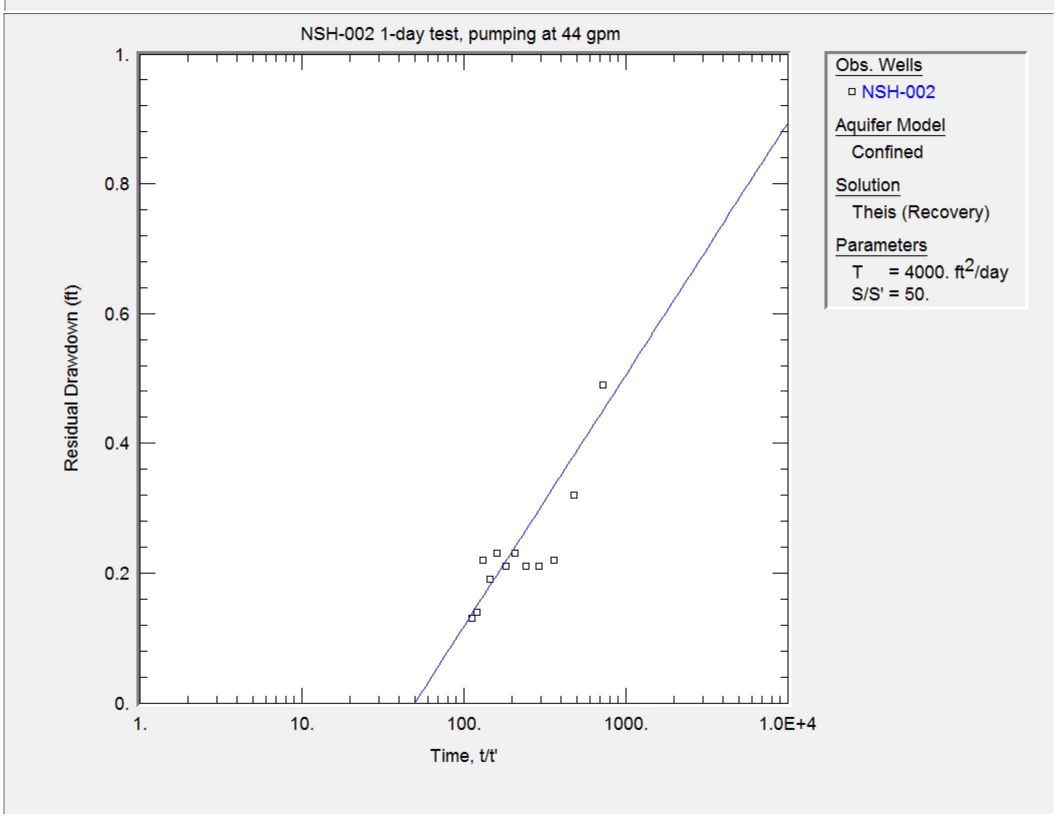


Figure 6

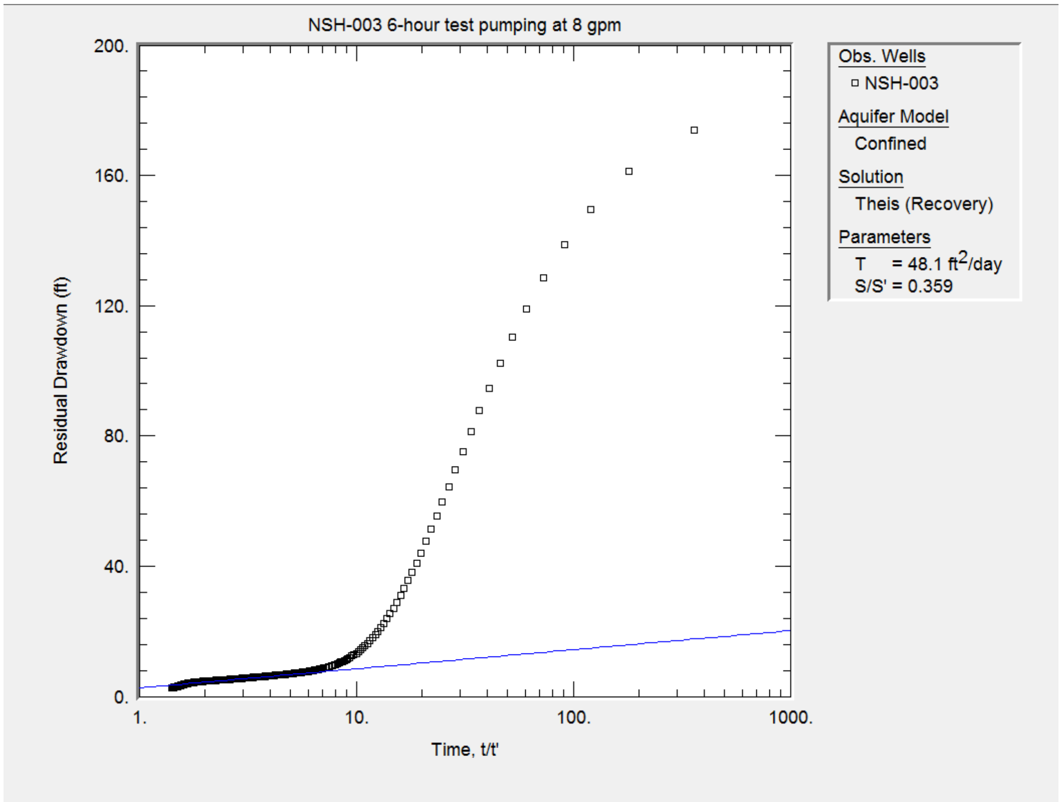


Figure 7

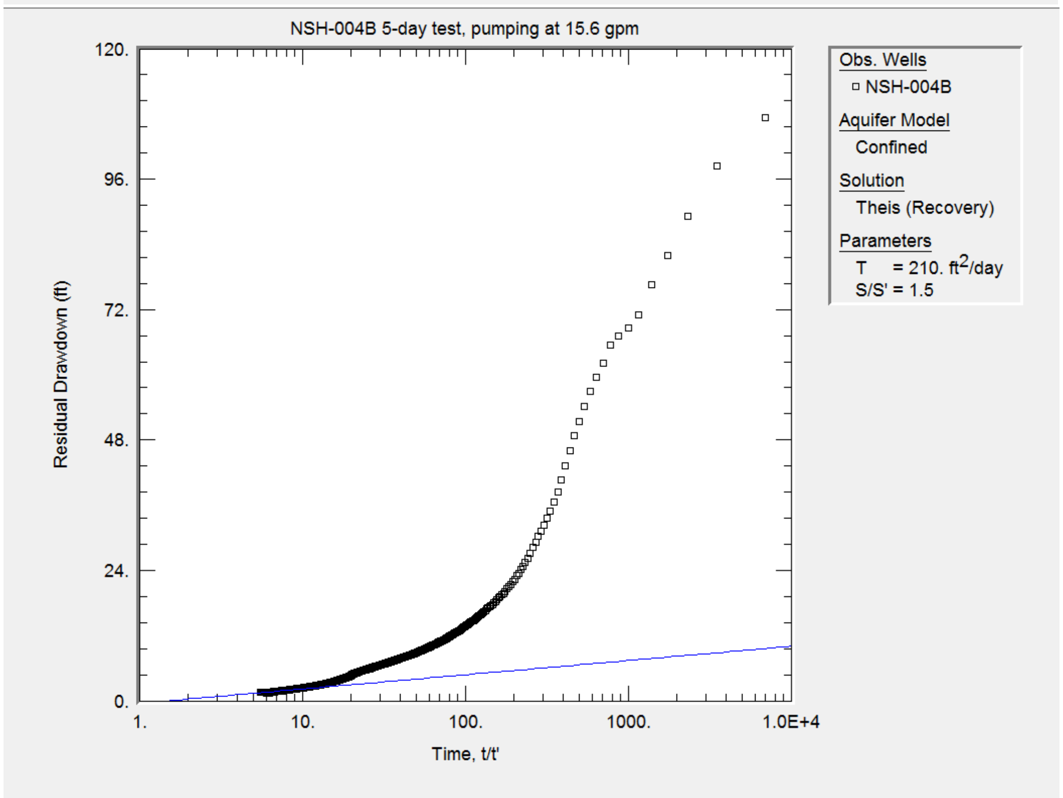


Figure 8

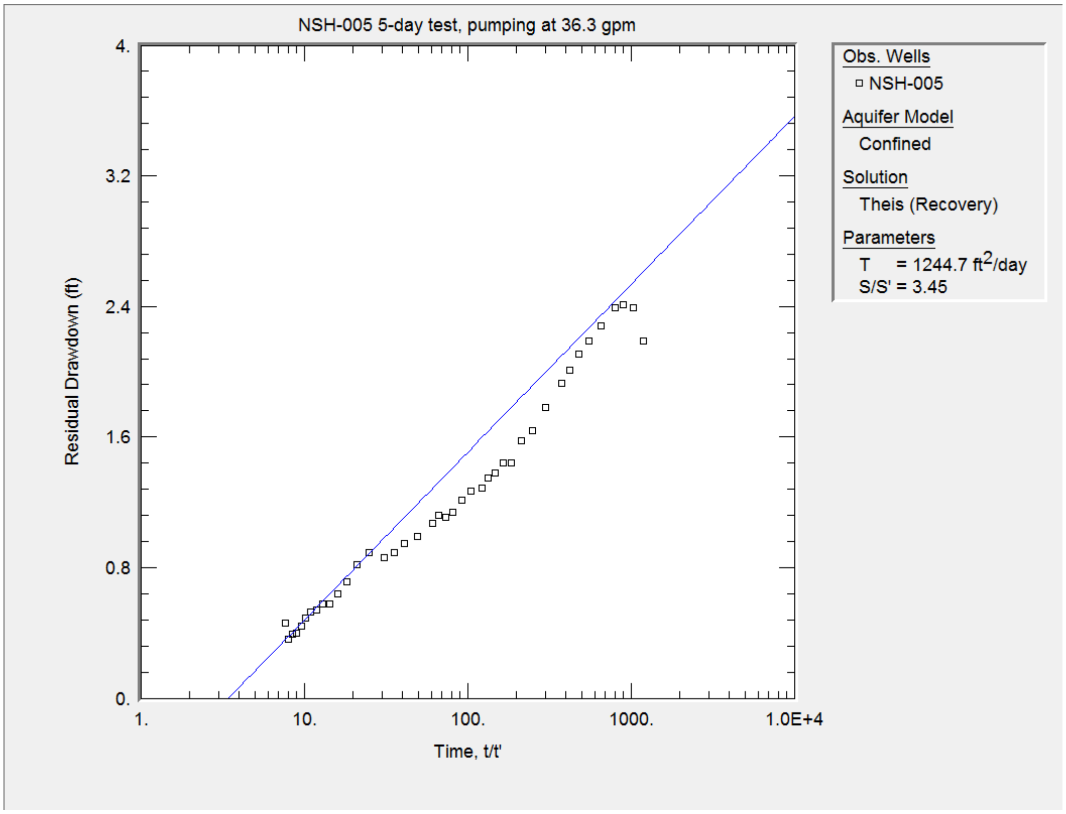


Figure 9

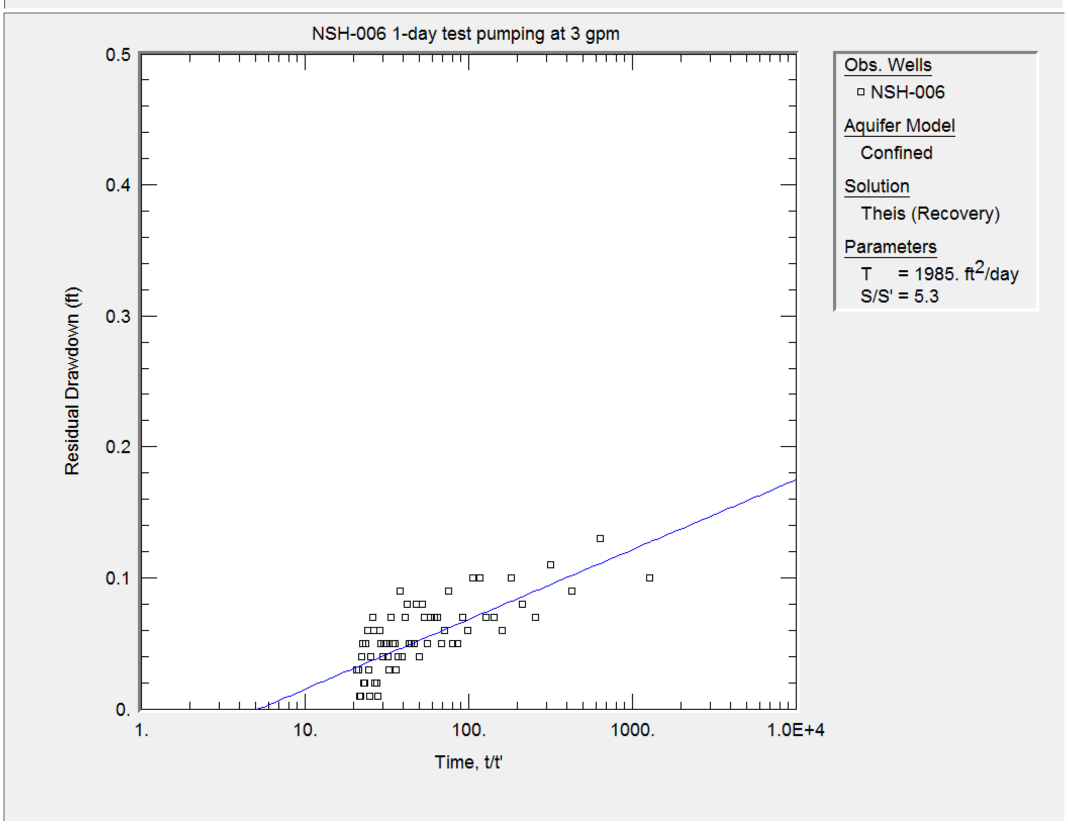


Figure 10

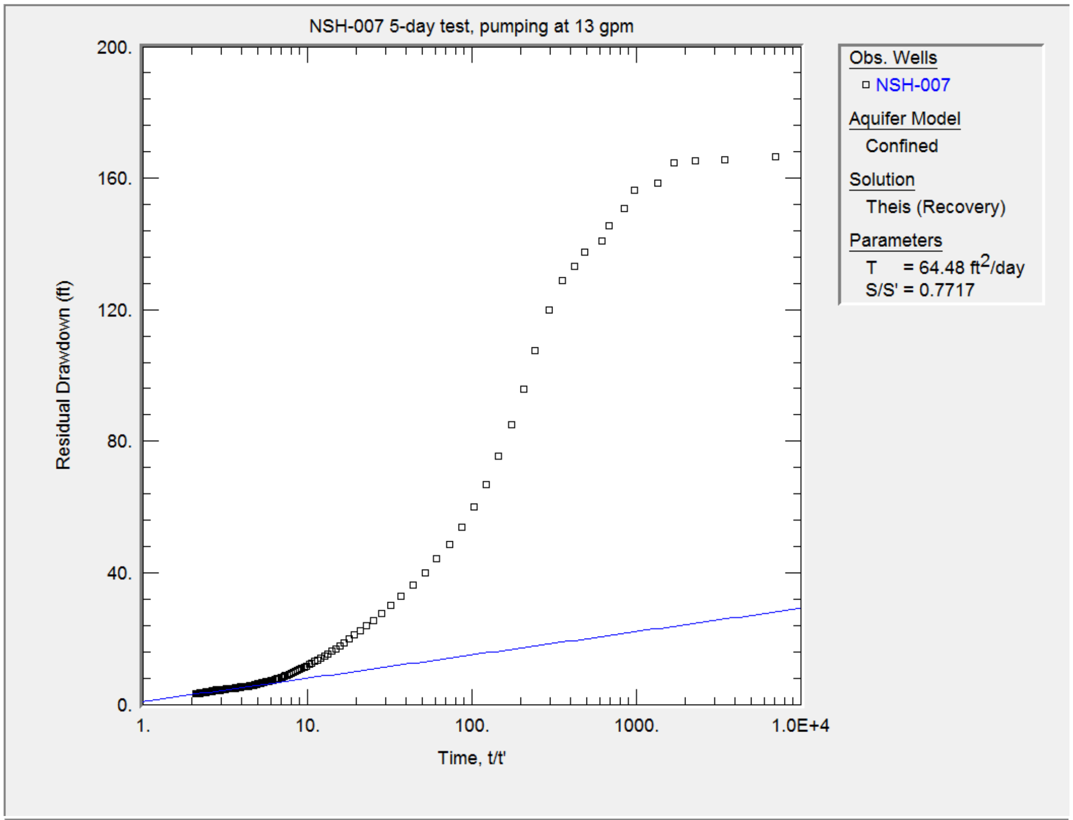


Figure 11

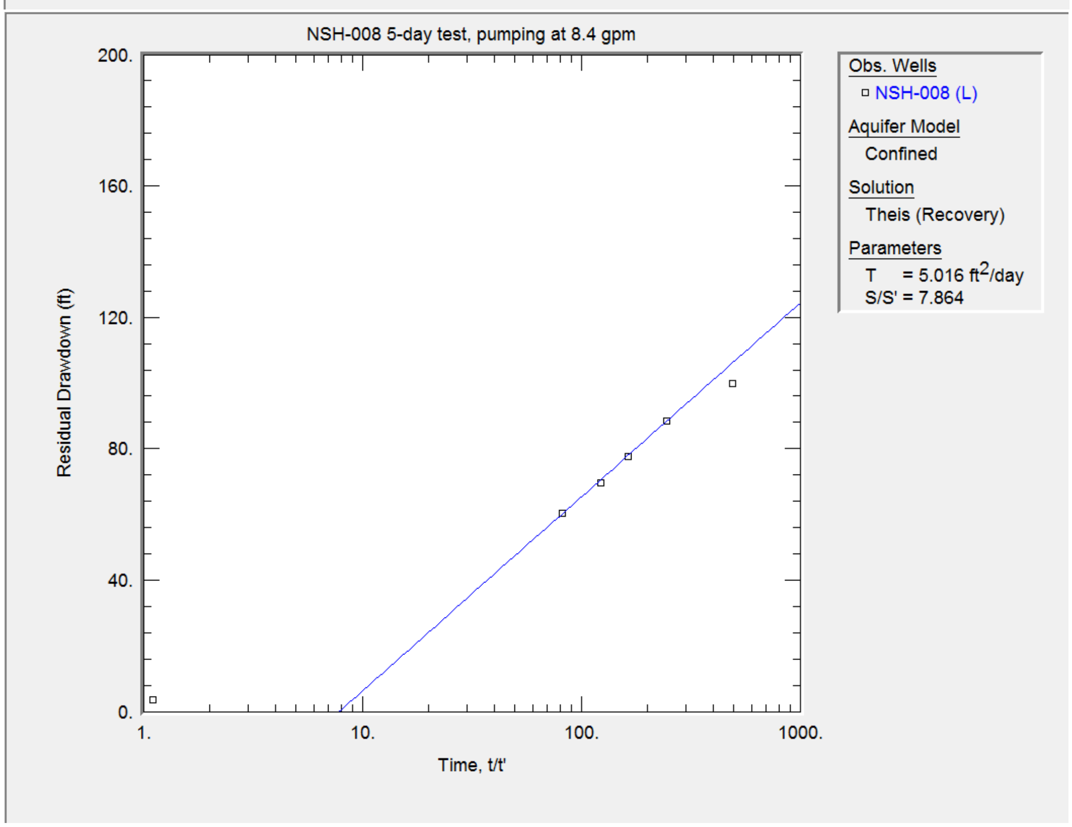


Figure 12

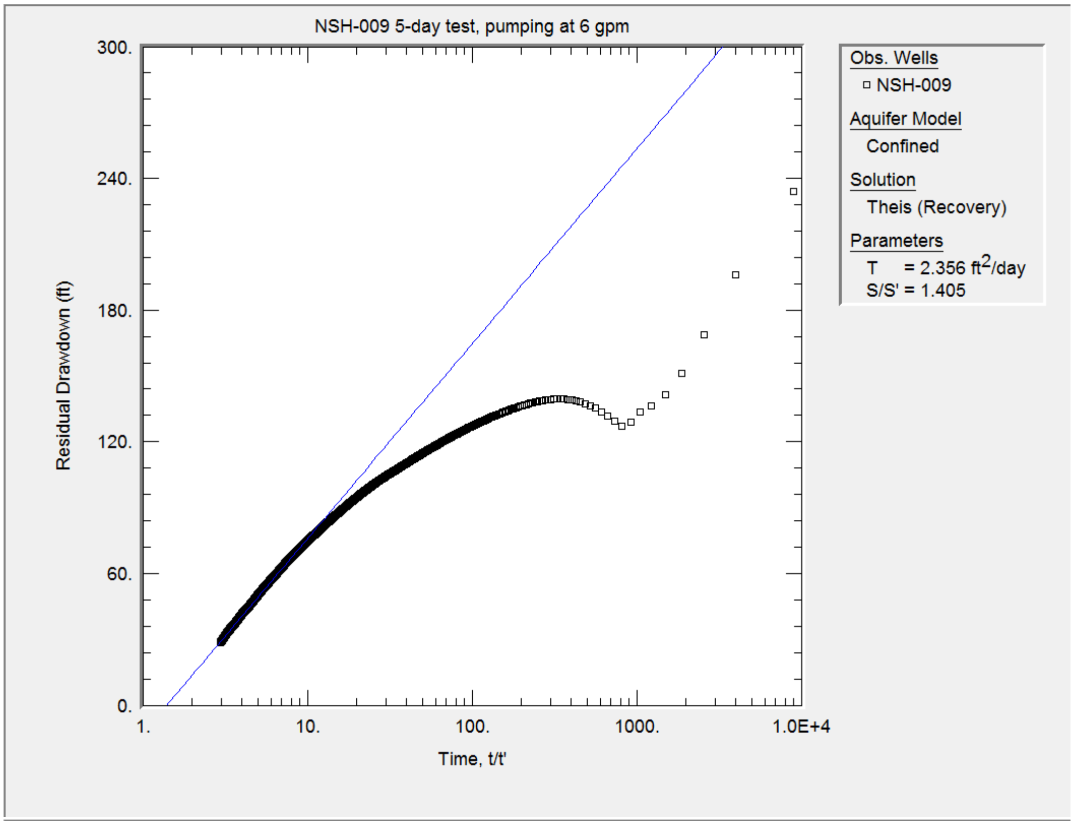


Figure 13

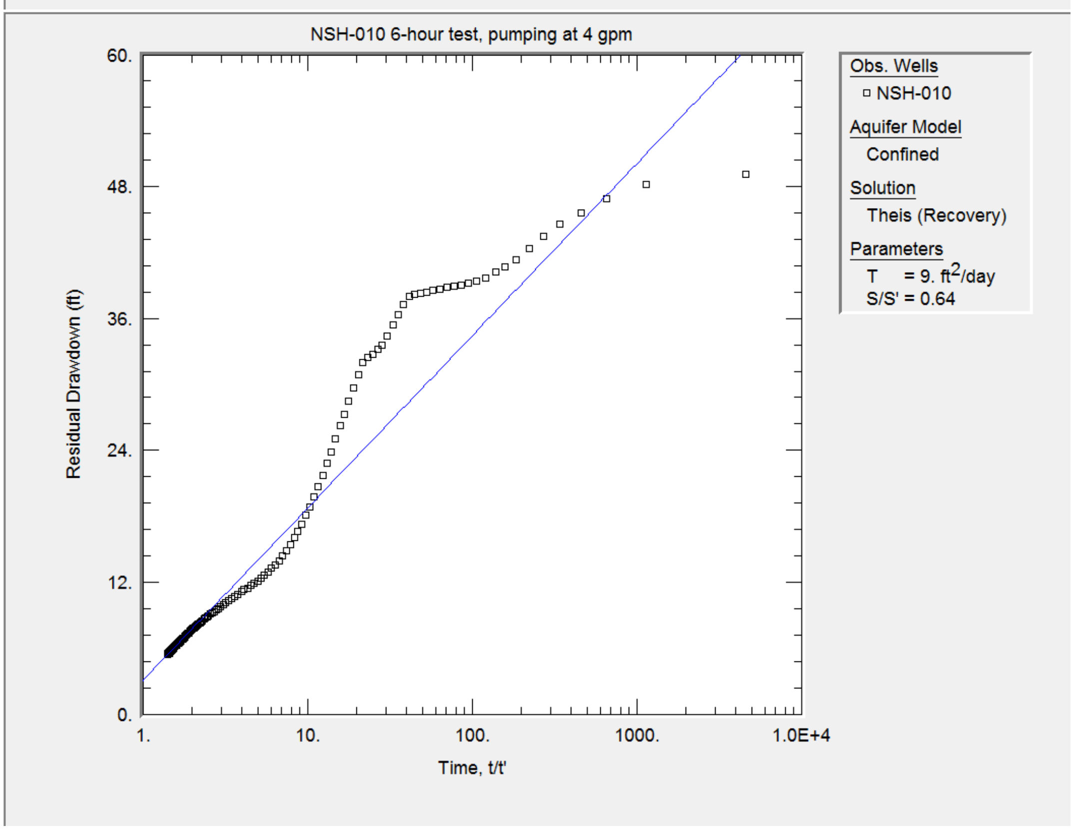


Figure 14

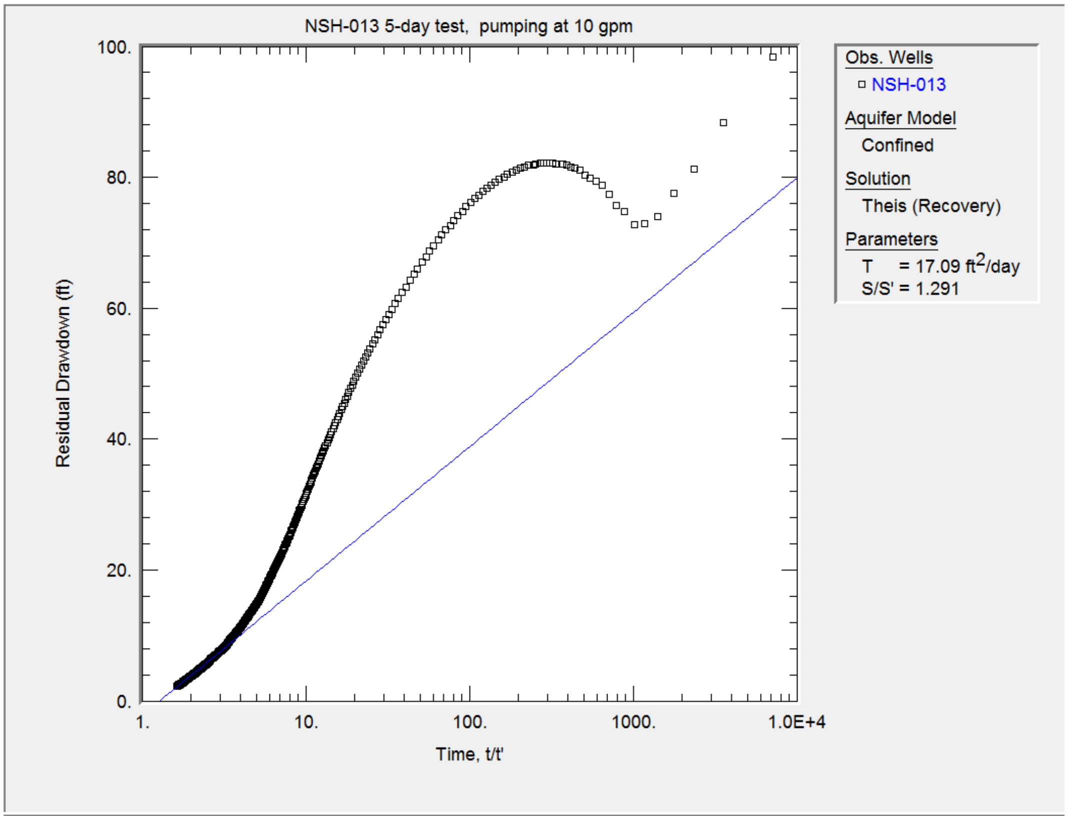


Figure 15

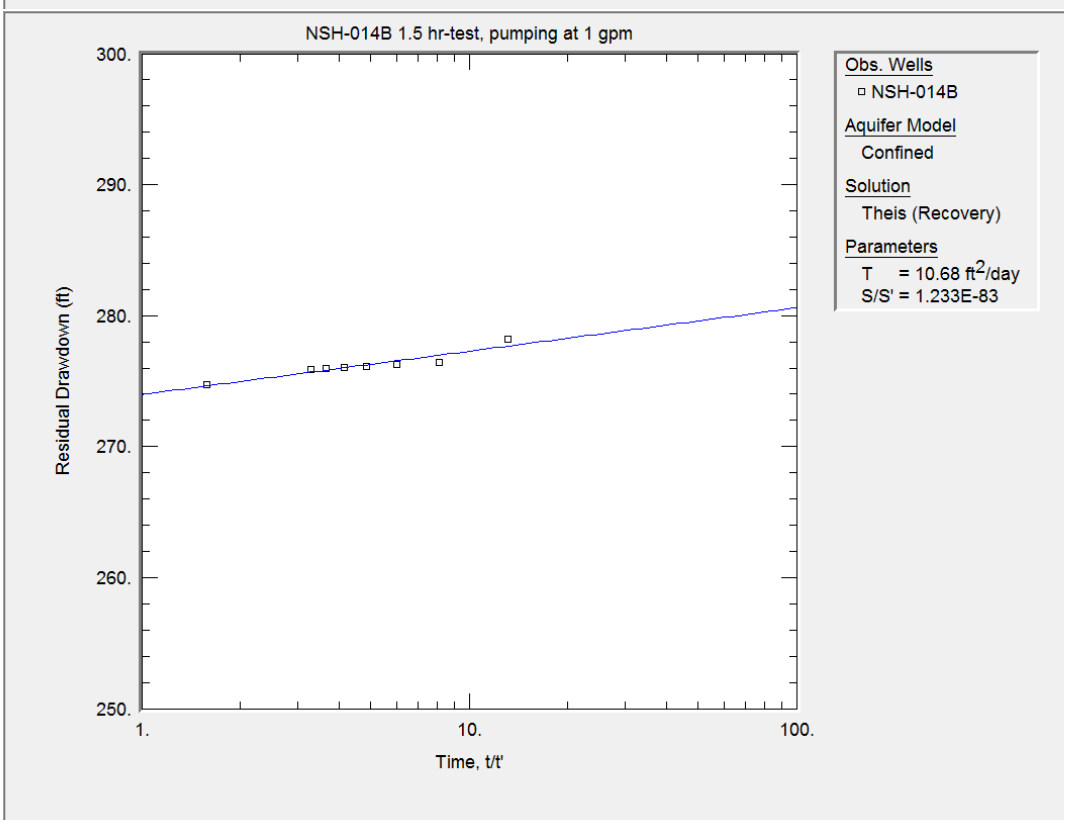


Figure 16

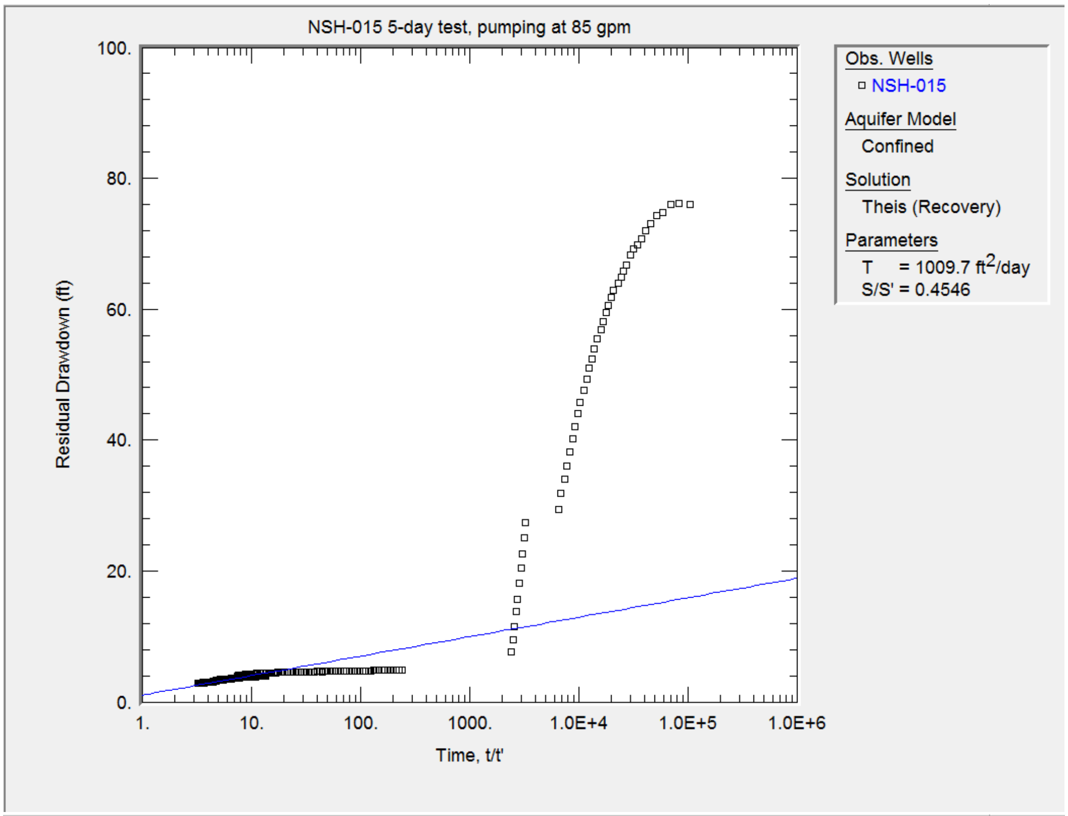


Figure 17

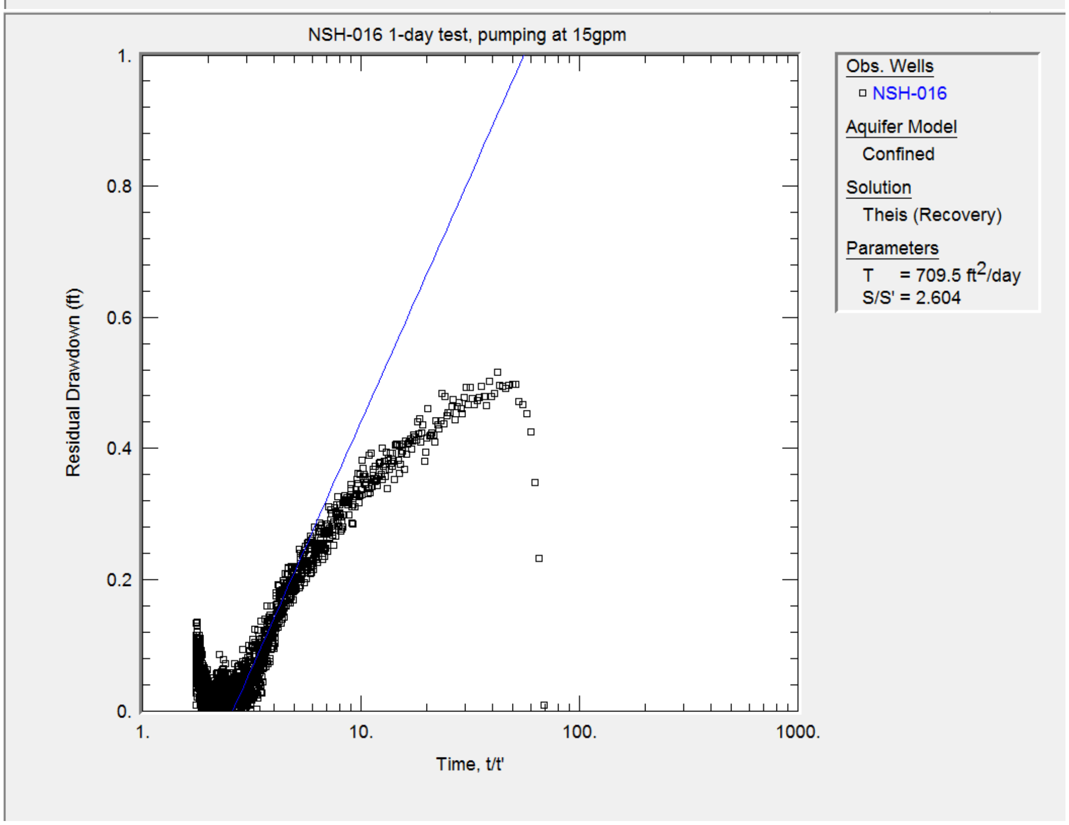


Figure 18

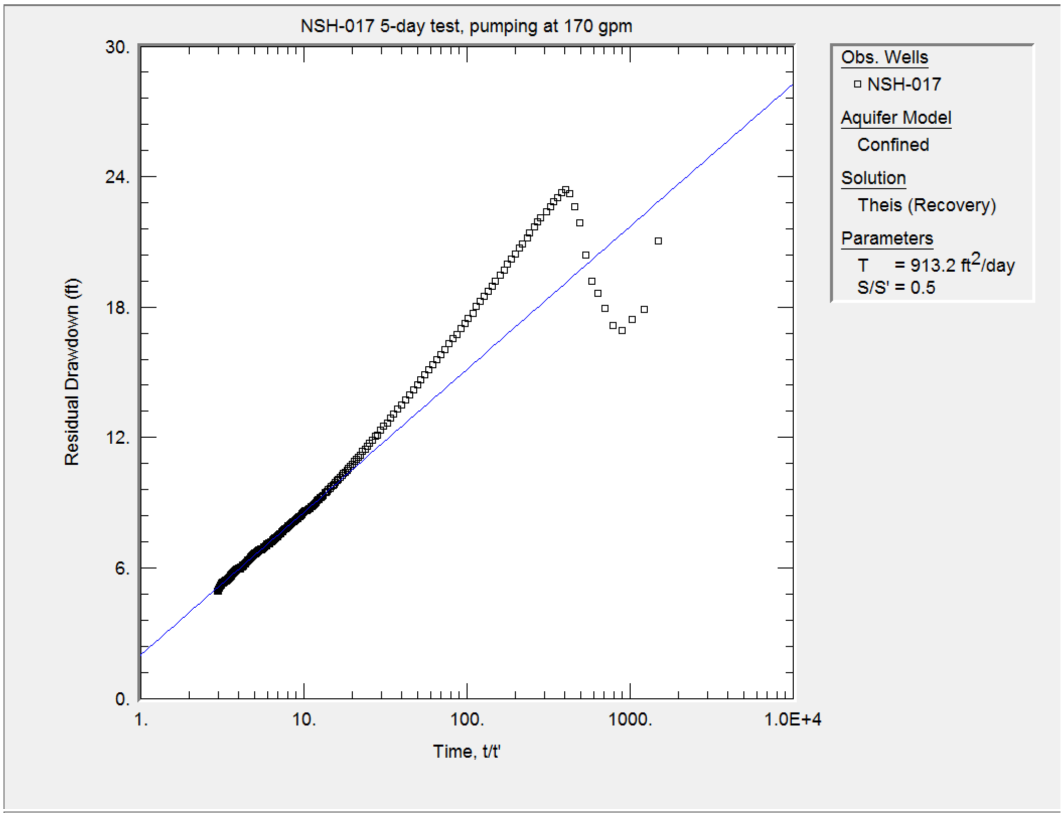


Figure 19

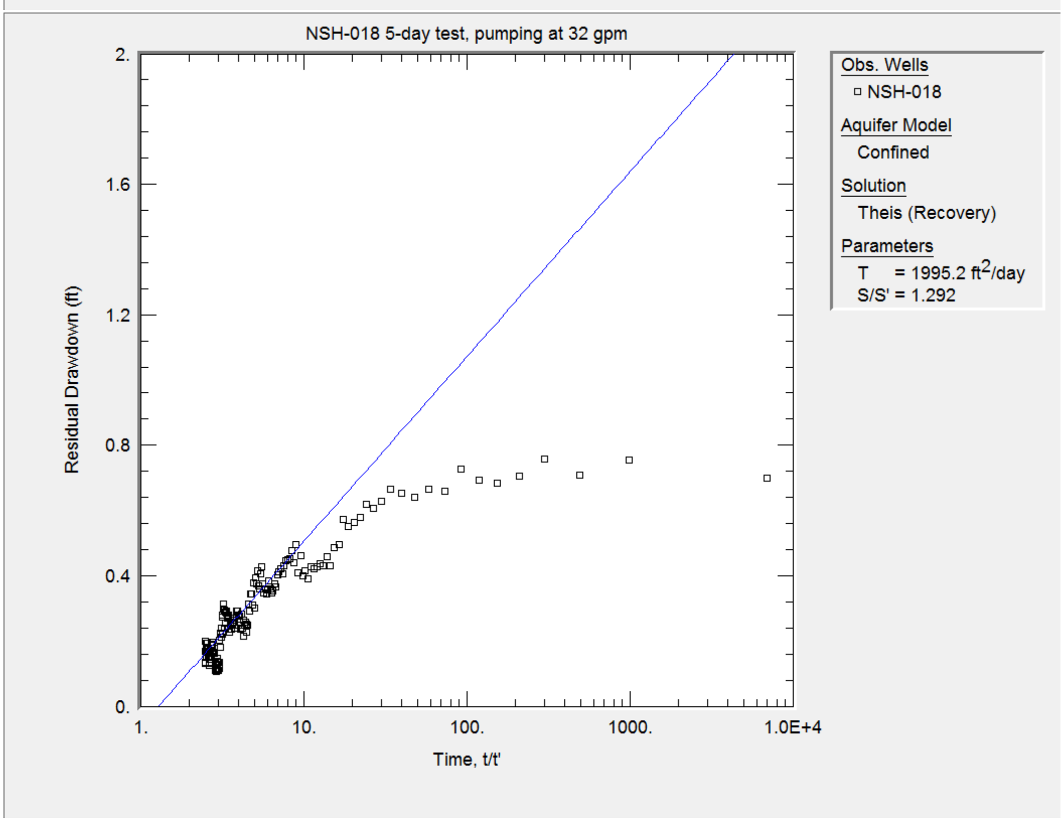


Figure 20

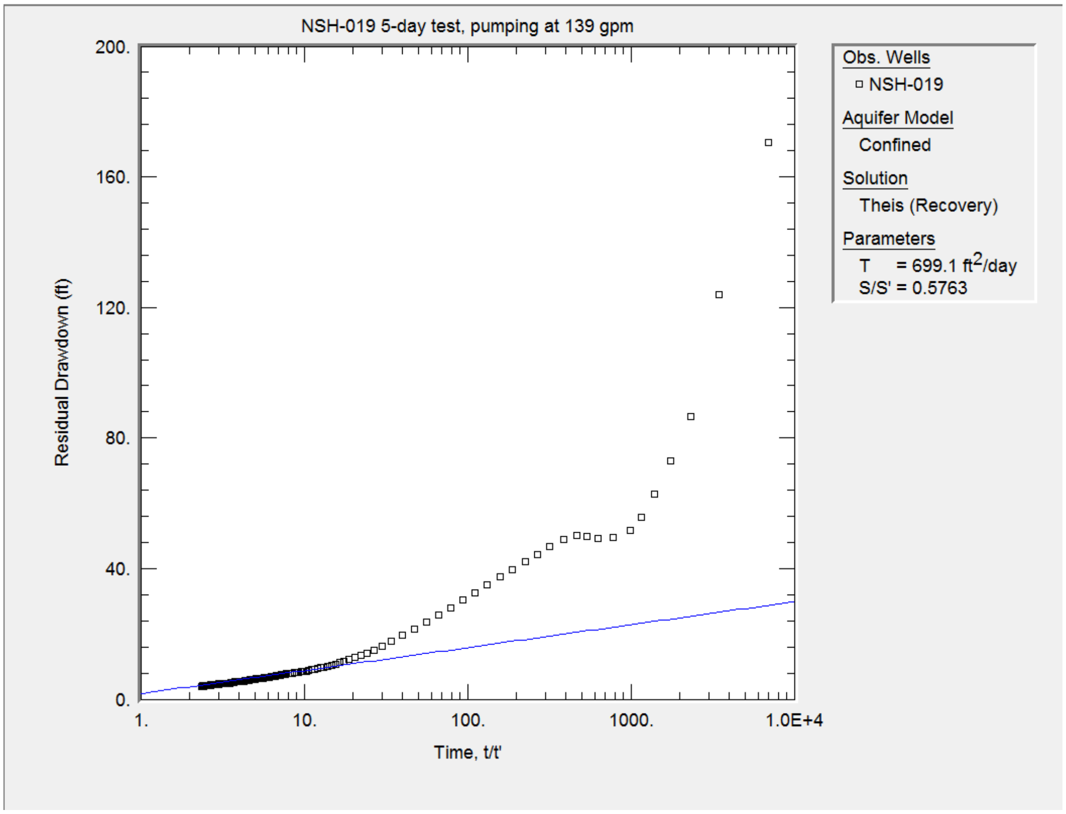


Figure 21

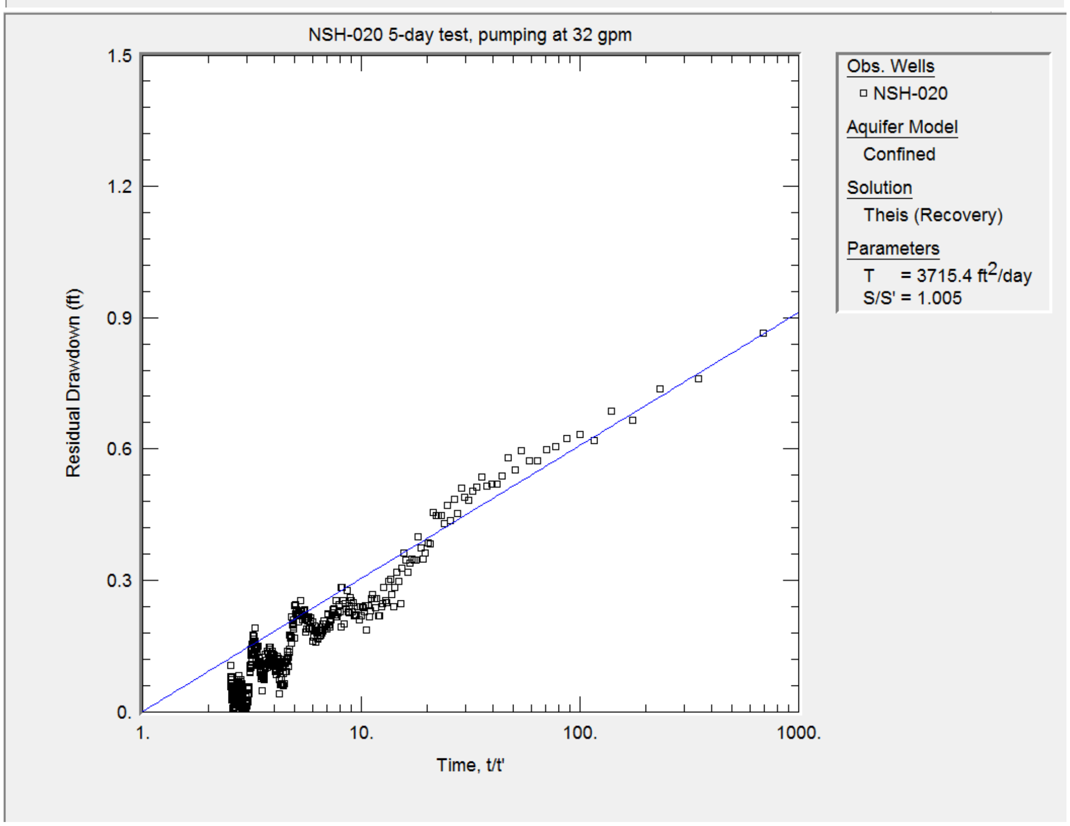


Figure 22

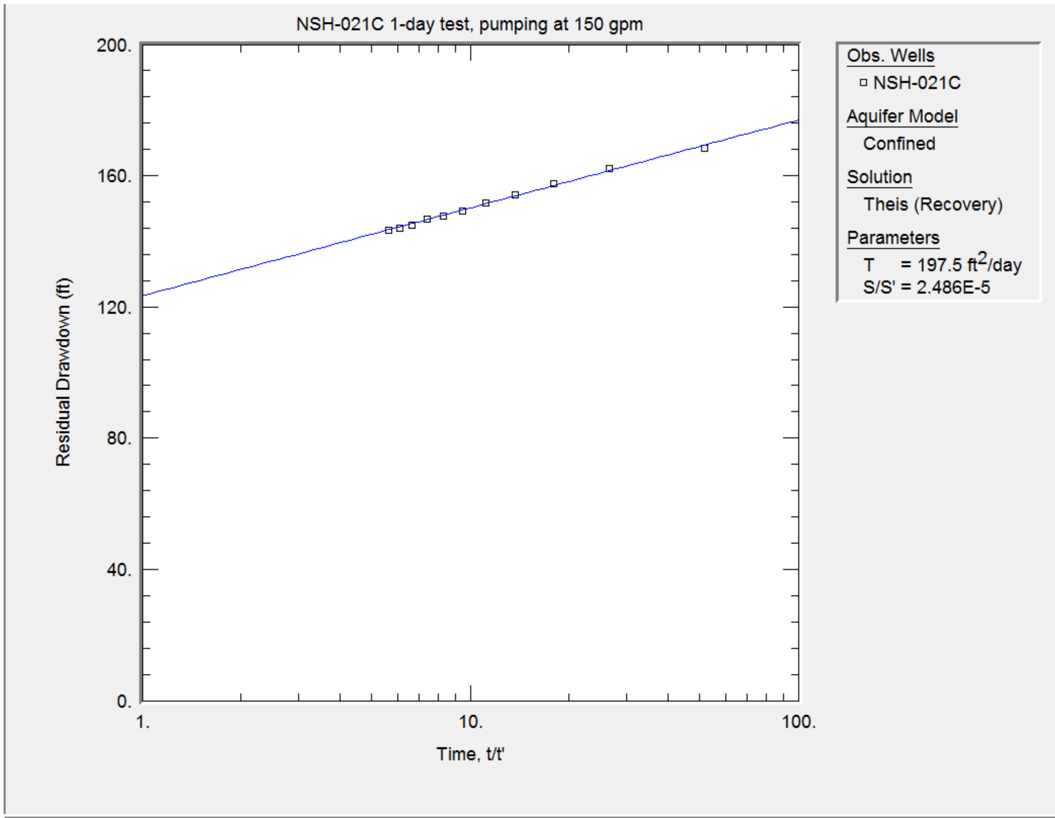


Figure 23

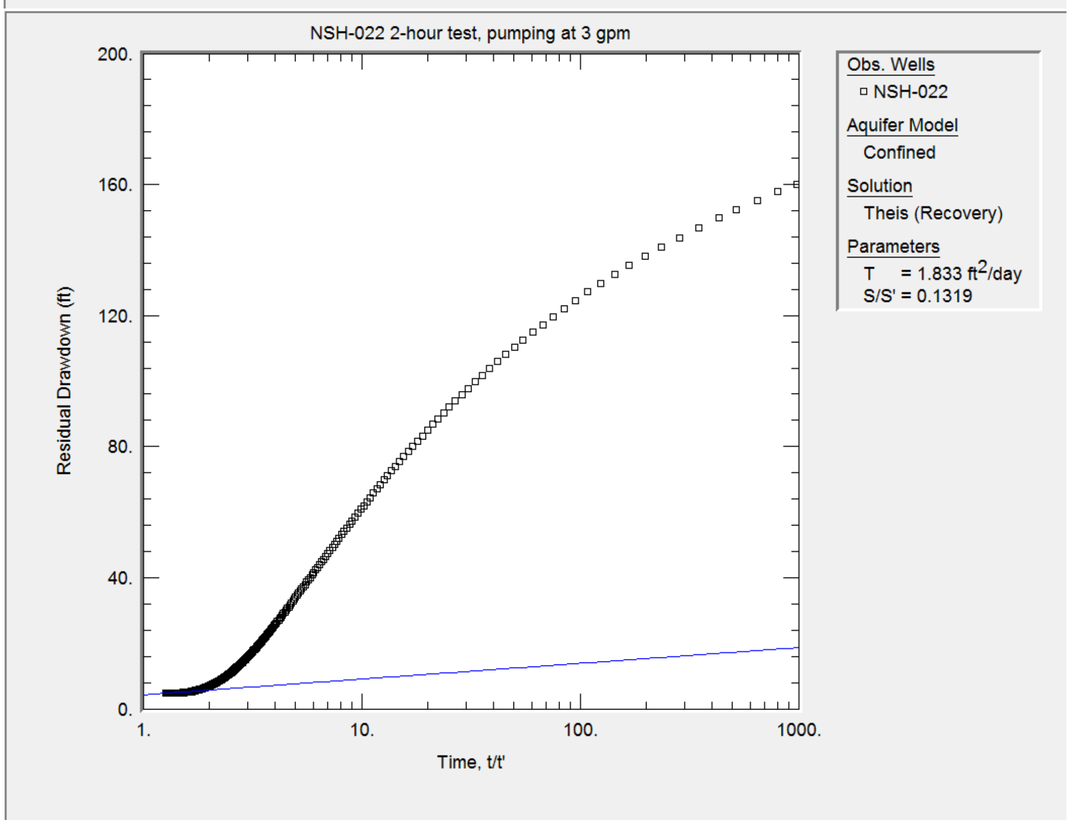


Figure 24

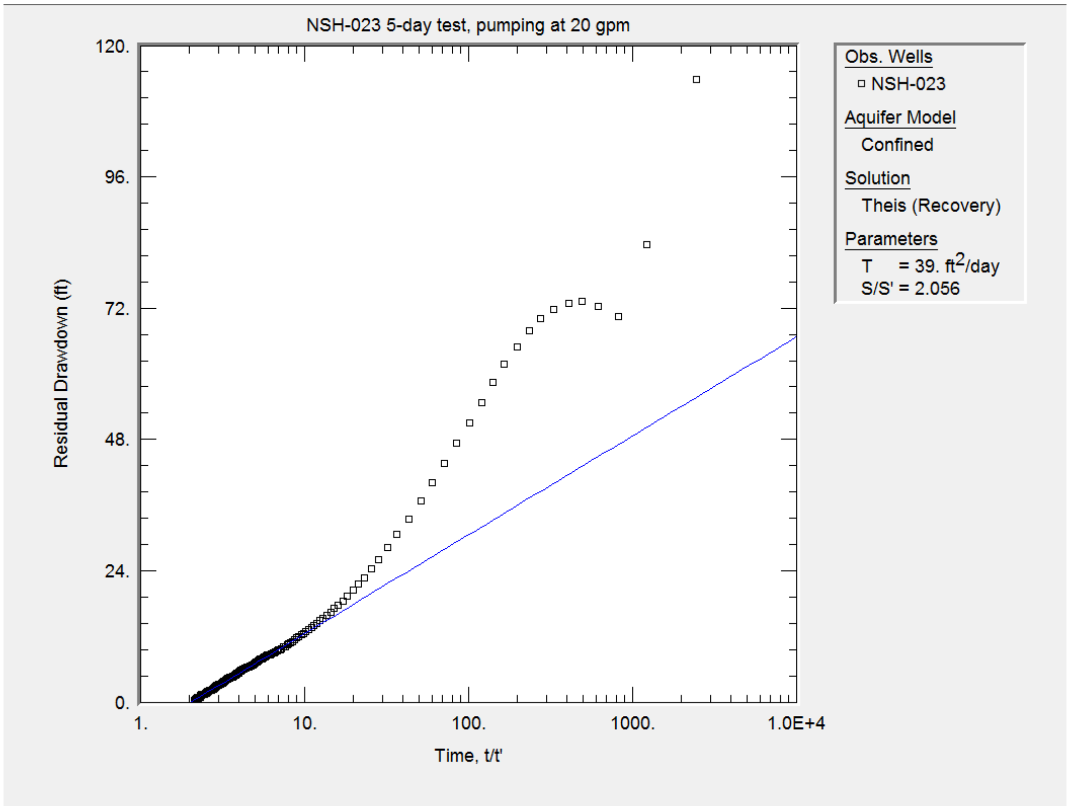


Figure 25

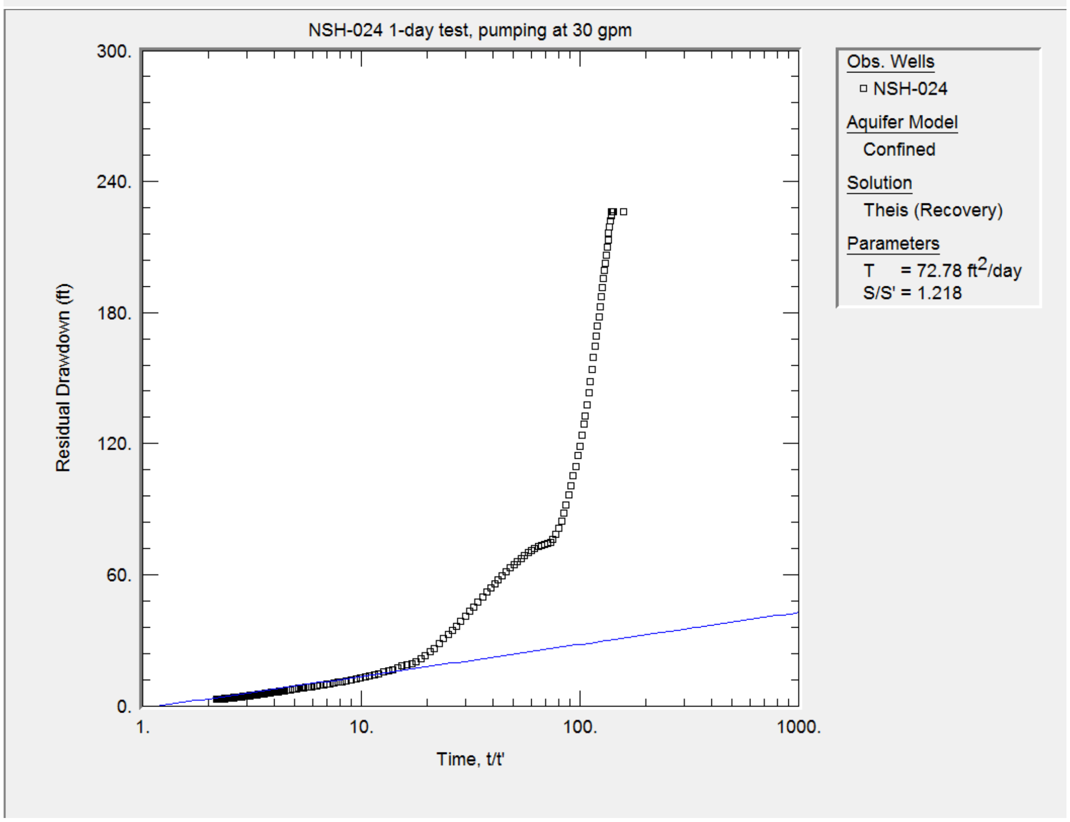


Figure 26

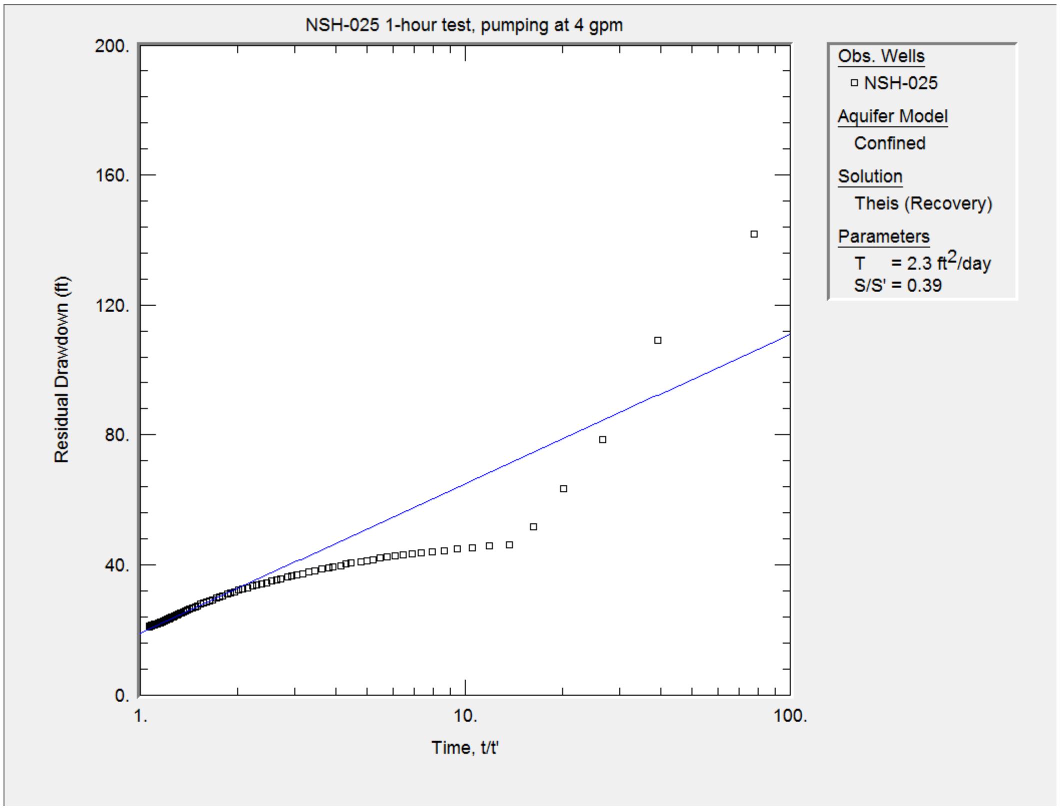
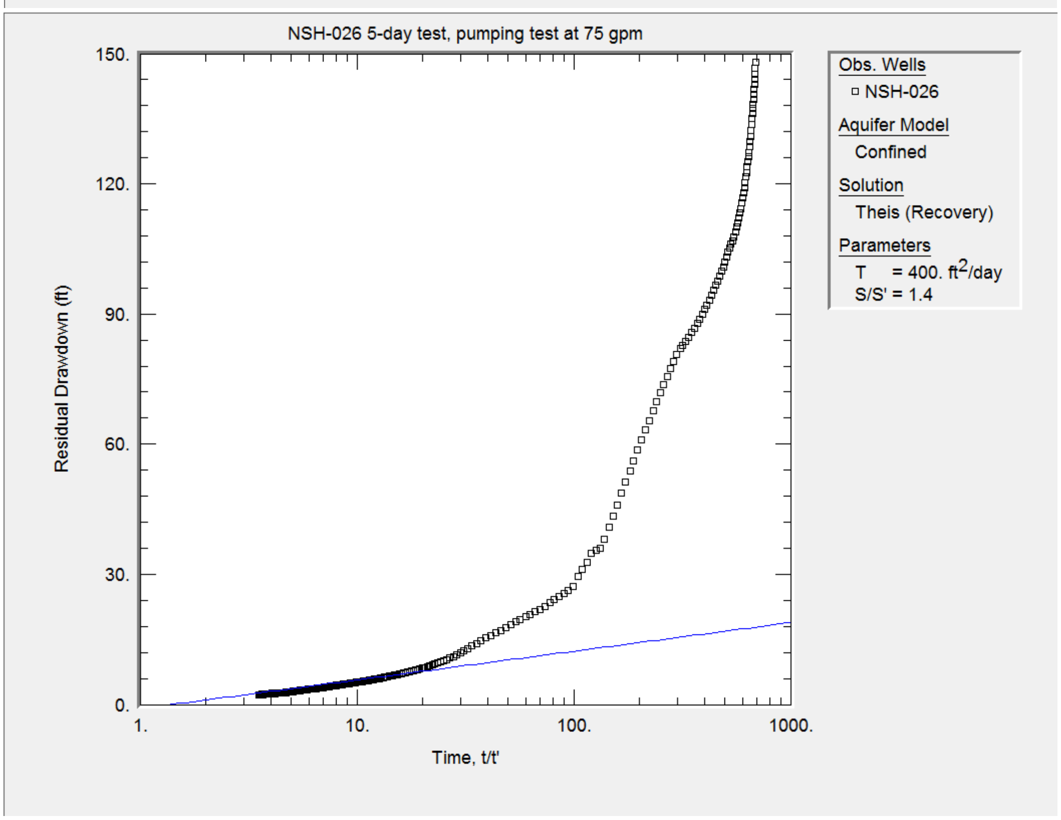


Figure 27



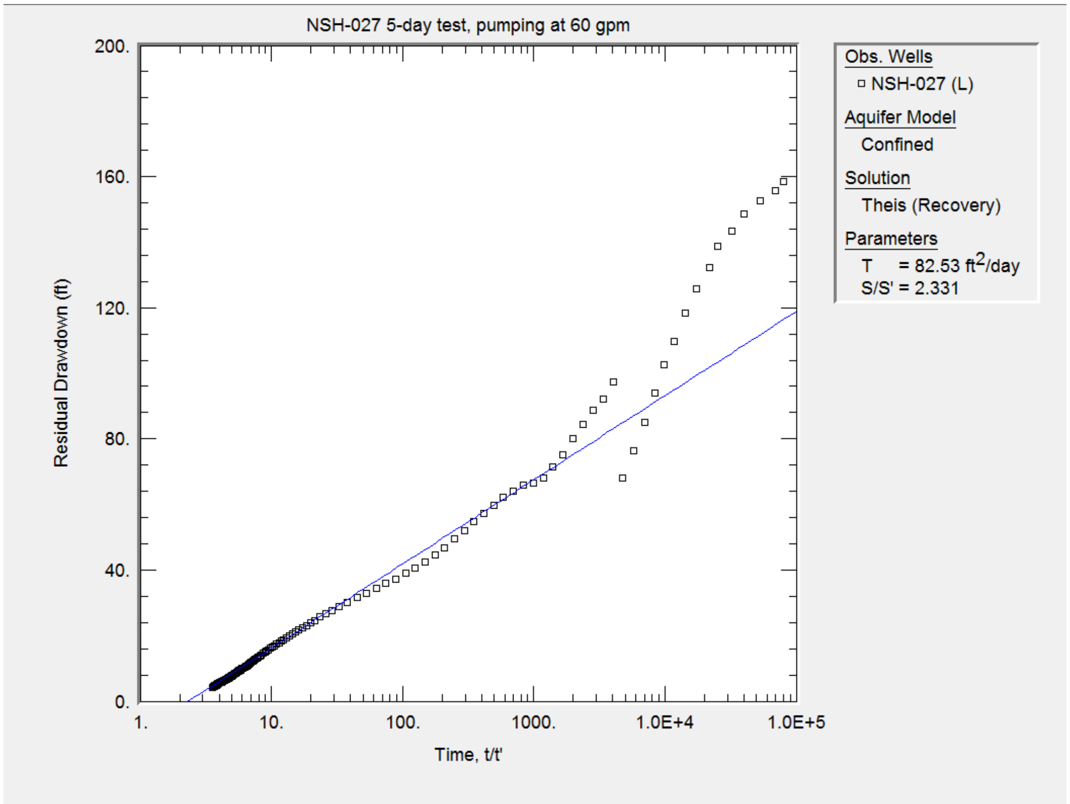


Figure 28

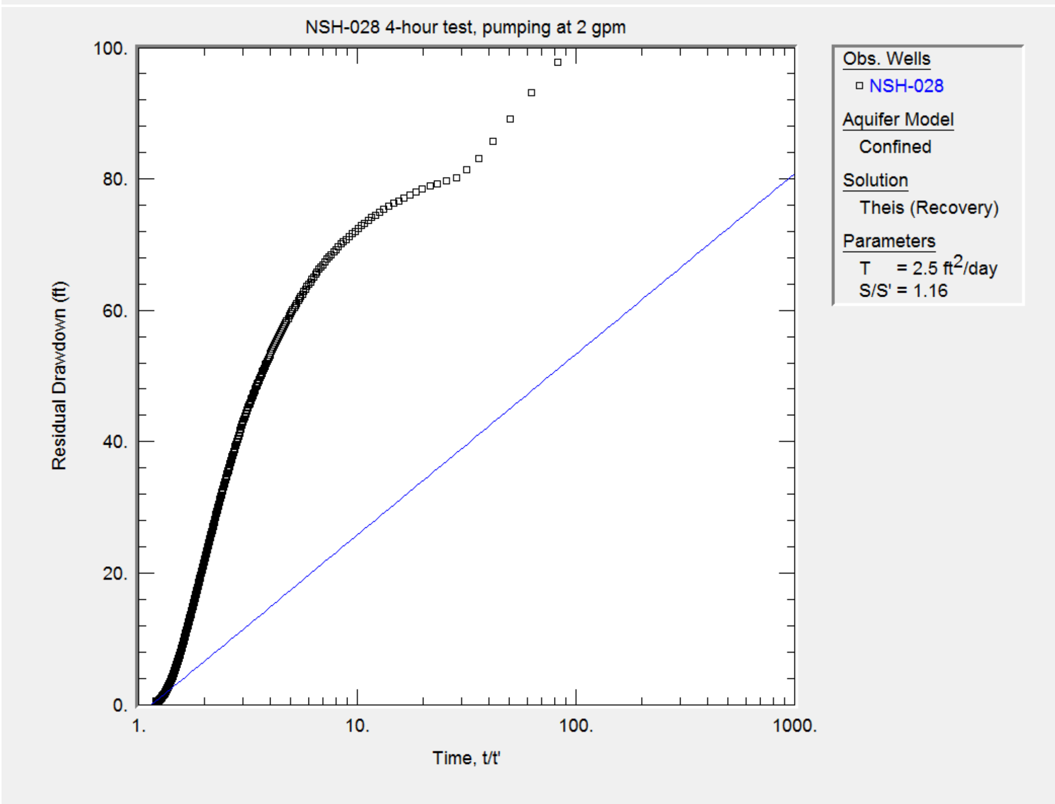
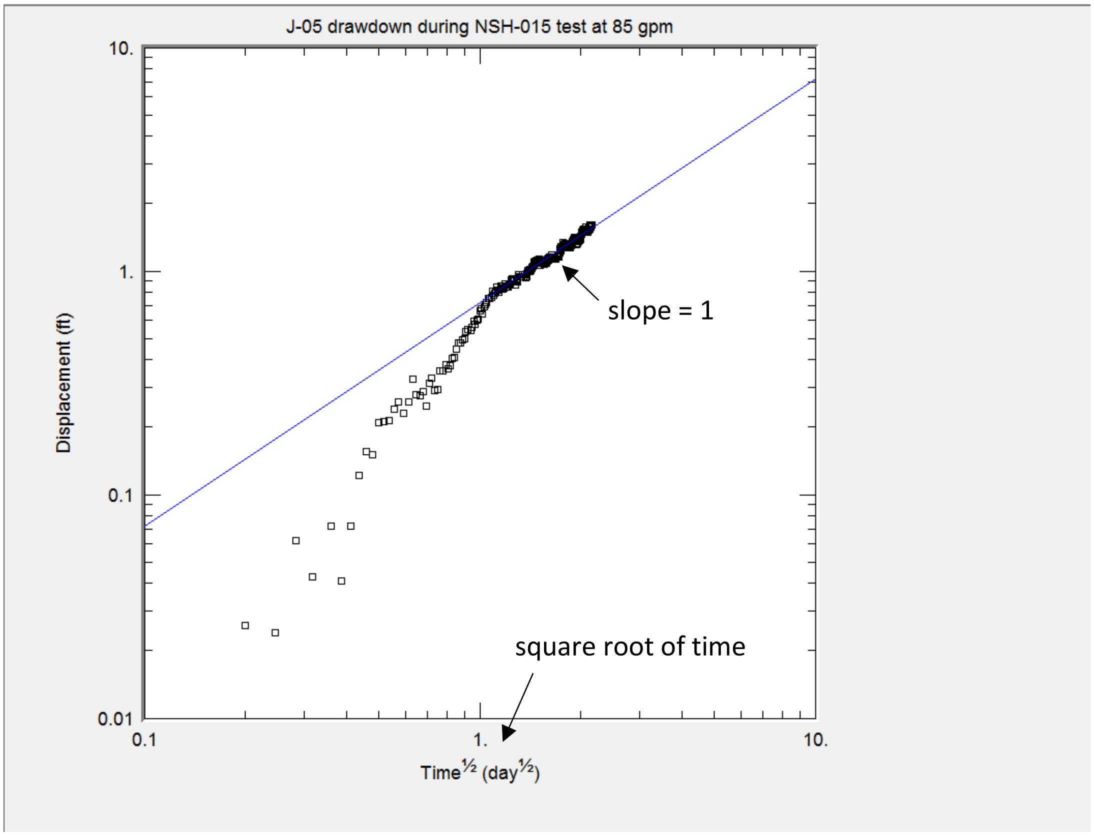


Figure 29

FIGURE 30

DIAGNOSTIC RESPONSE IN DOUBLE POROSITY MEDIA

Figure 30



J-05 drawdown during NSH-015 test at 85 gpm
10.
1.
0.1
0.01
Displacement (ft)
0.1
1.
10.
Time½ (day½)
slope = 1
square root of time

FIGURE 31 through 48.
PUMPTEST LAYOUT AND
ULTIMATE DRAWDOWNS

Figure 31

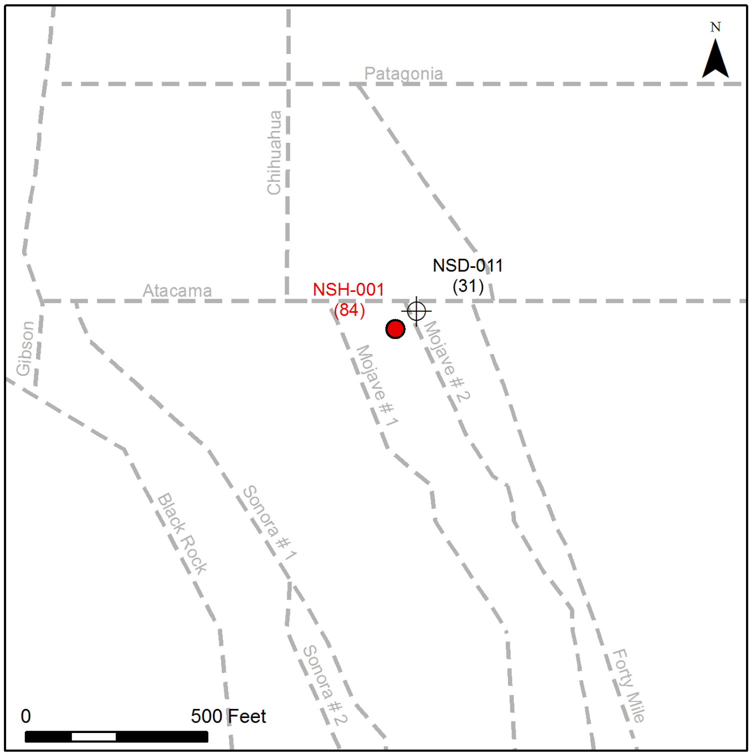


Figure 32

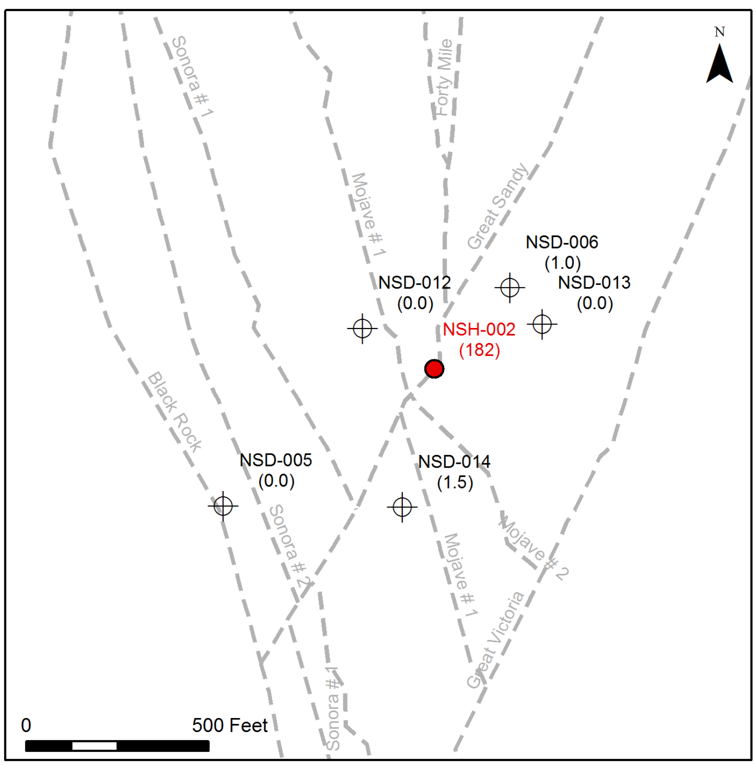


Figure 33

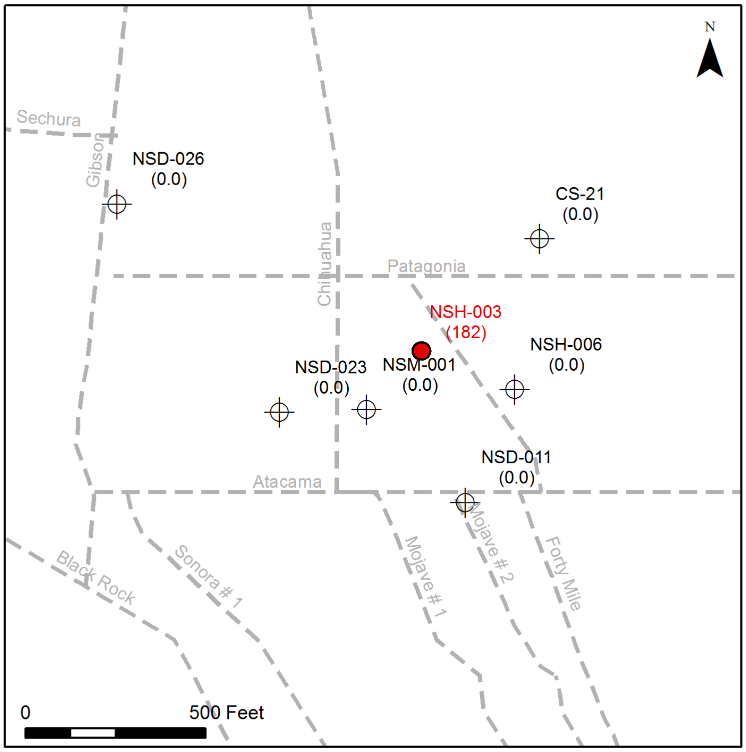


Figure 34

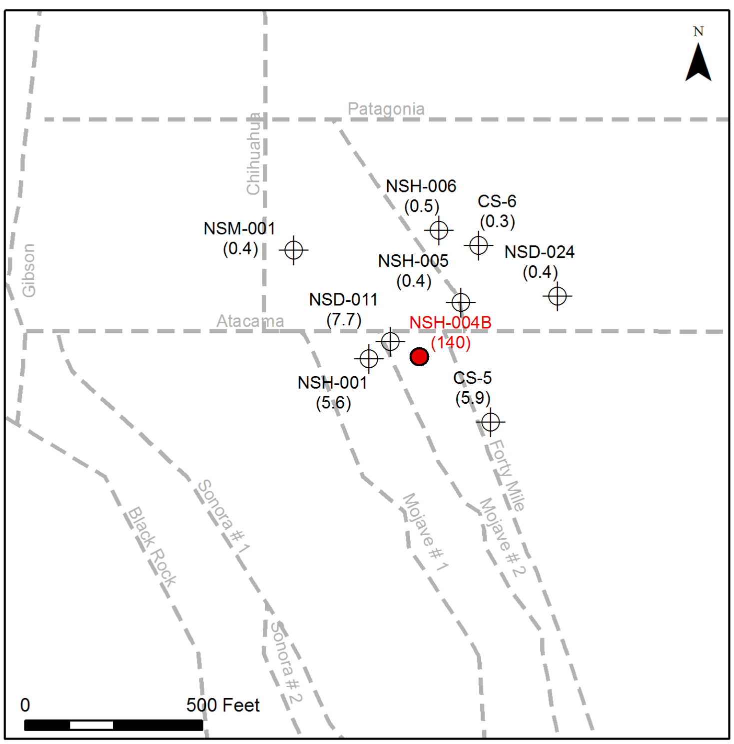


Figure 35

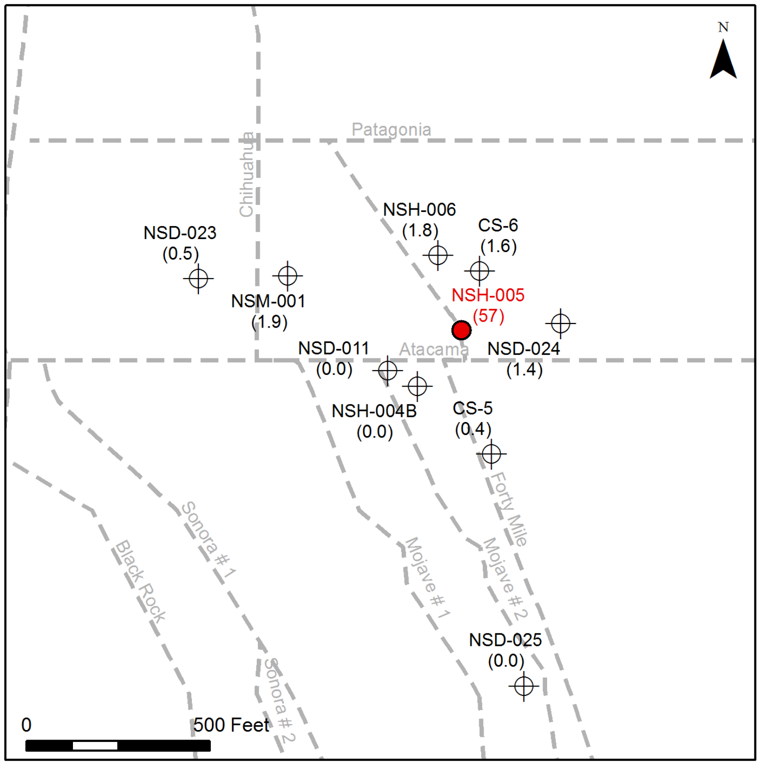


Figure 36

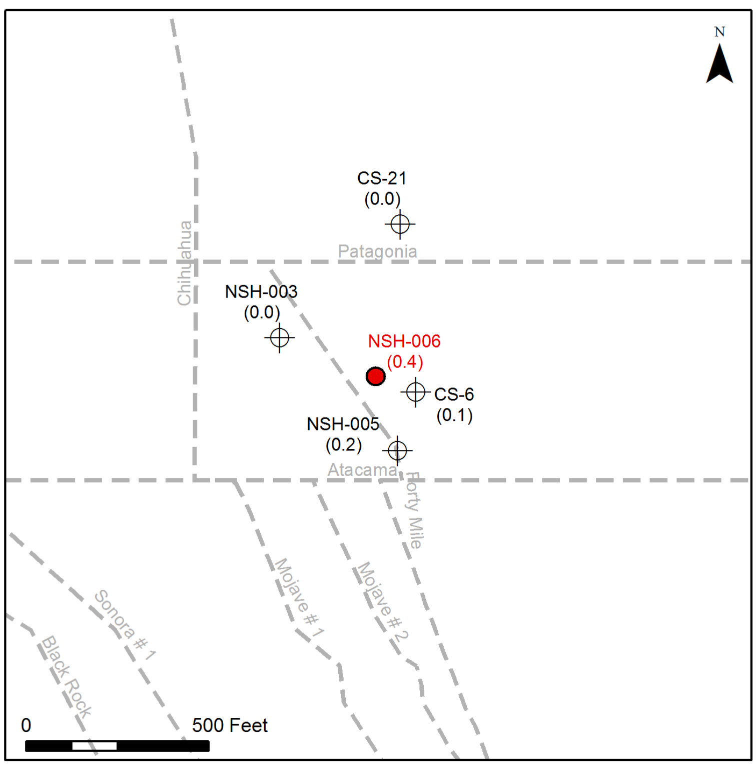


Figure 37

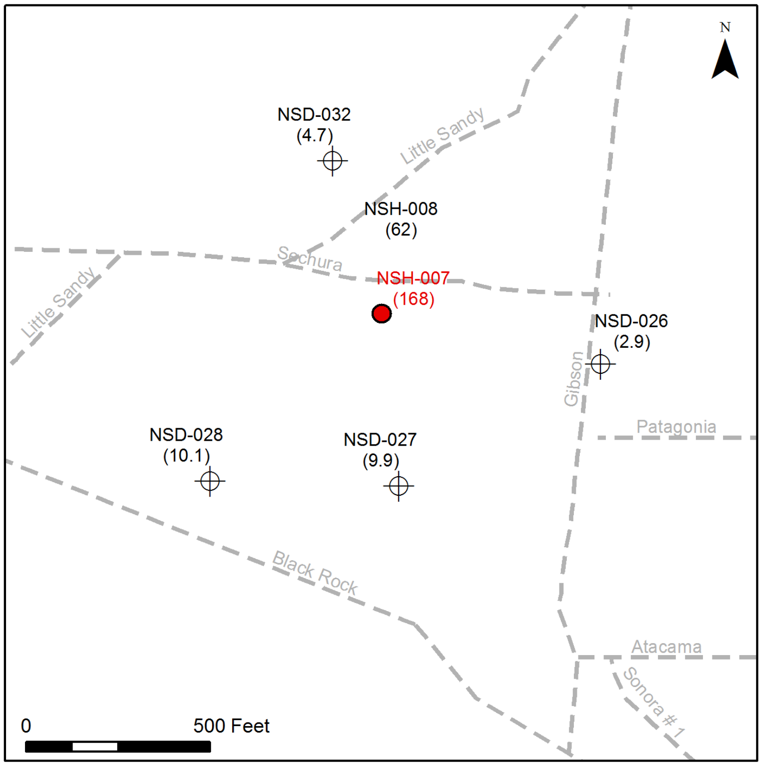


Figure 38

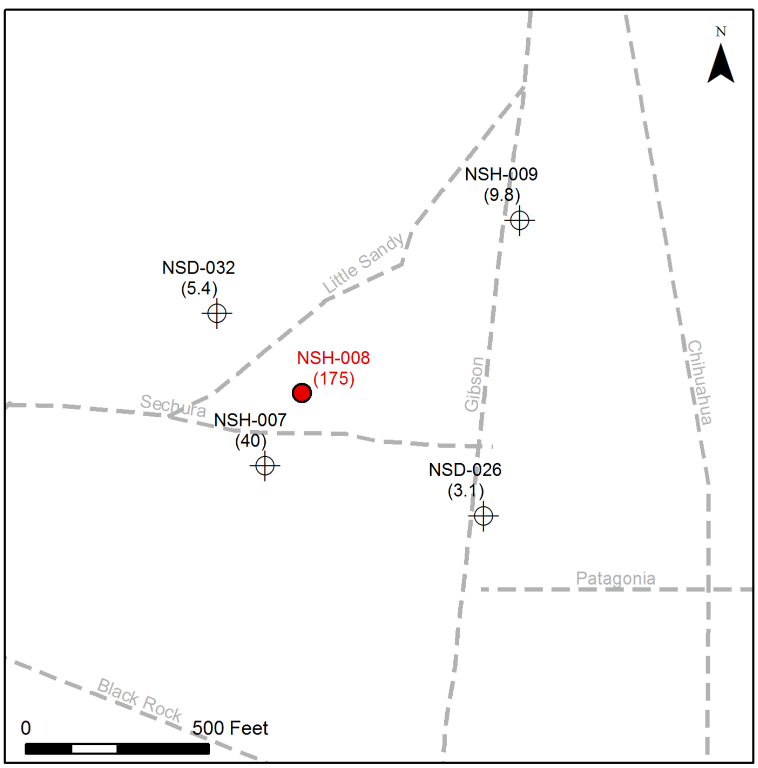


Figure 39

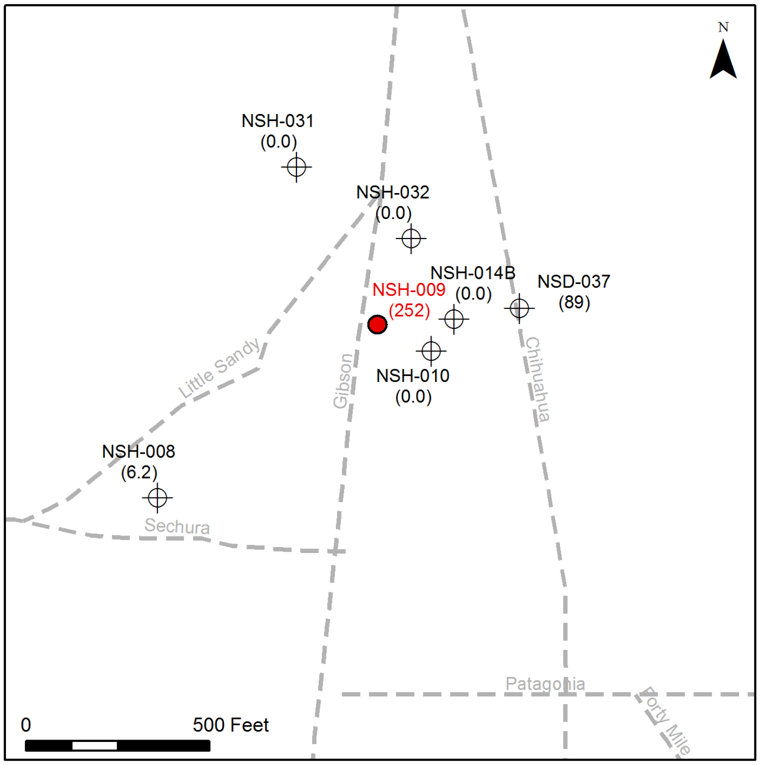


Figure 40

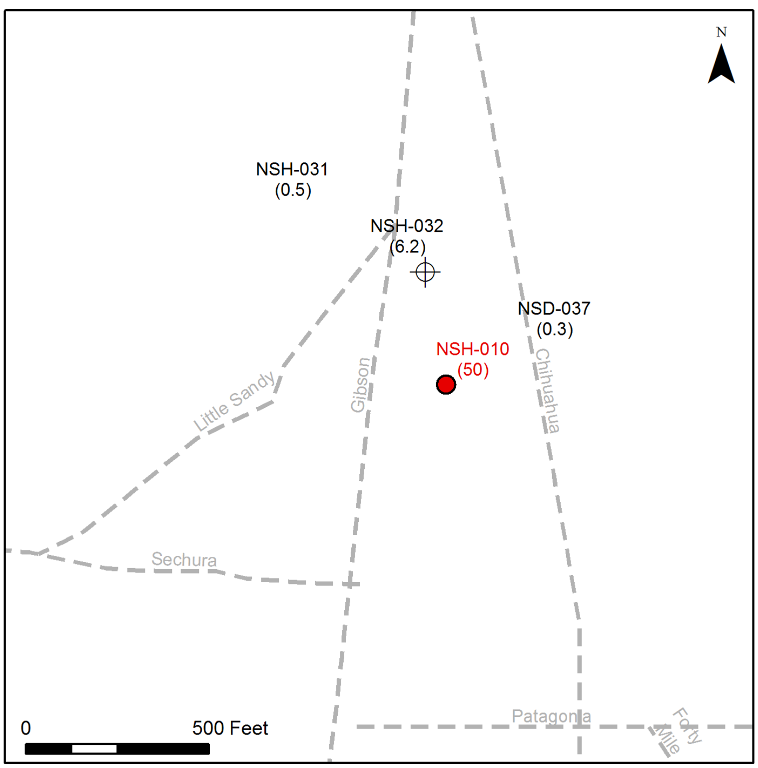


Figure 41

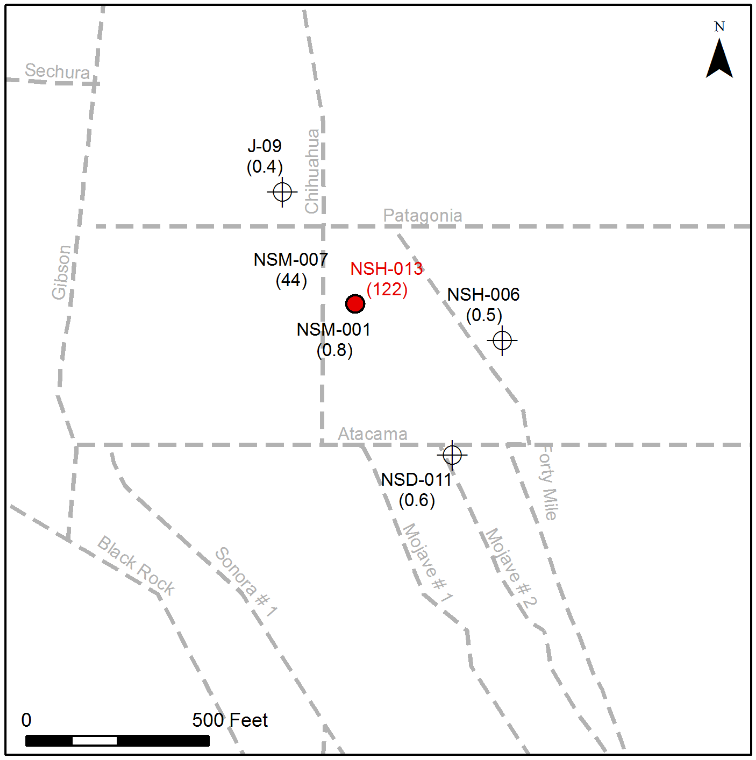


Figure 42

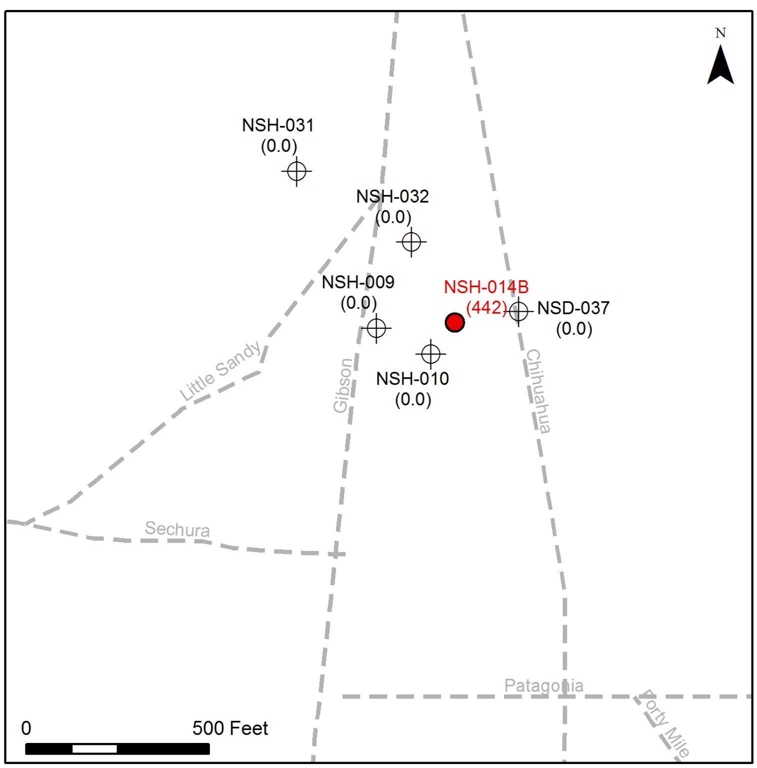


Figure 43

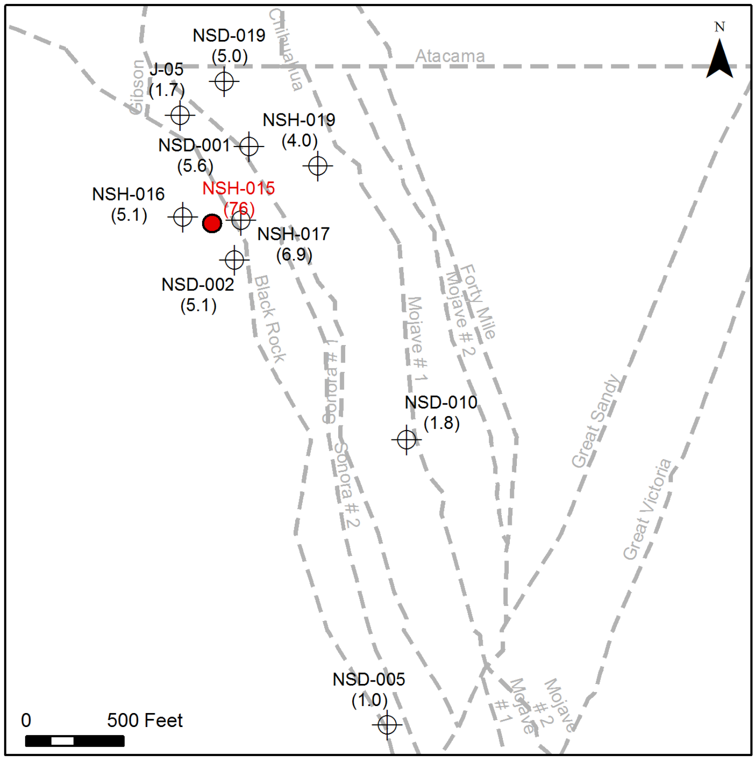


Figure 44

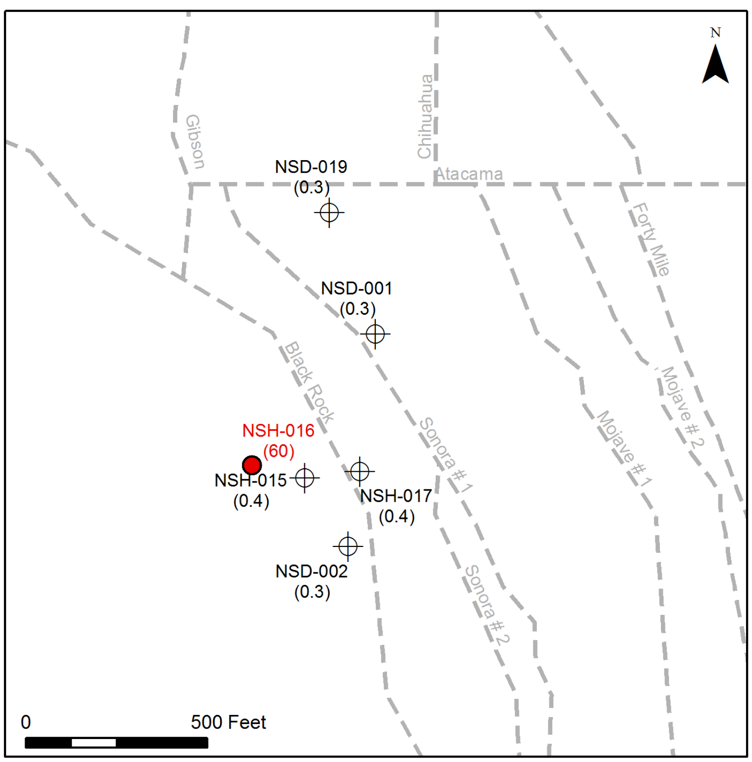


Figure 45

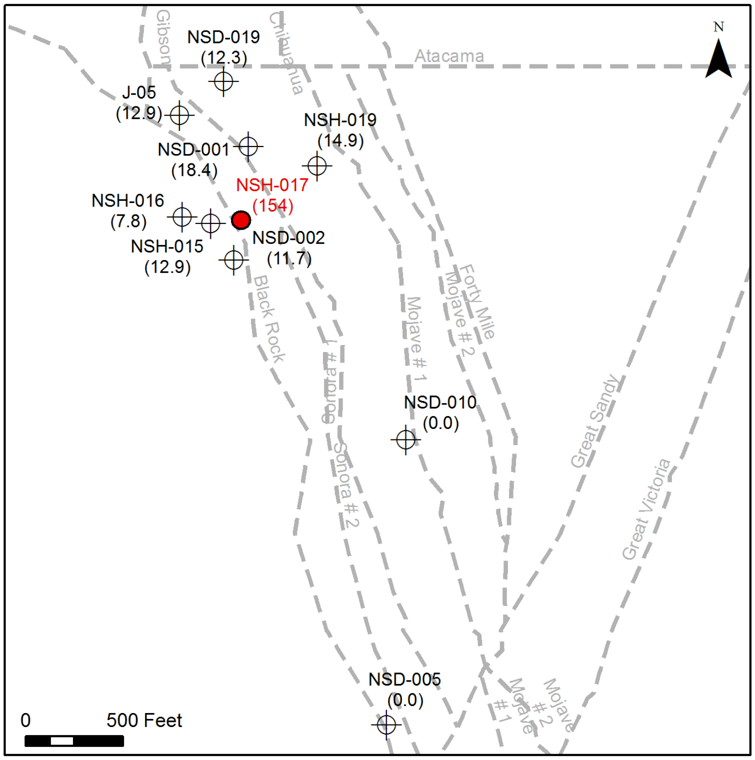
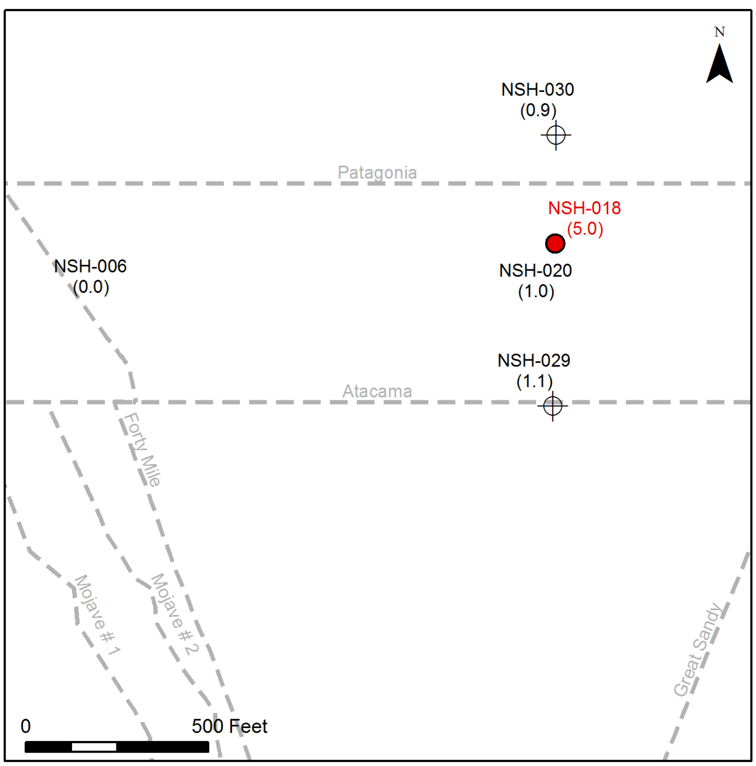


Figure 46



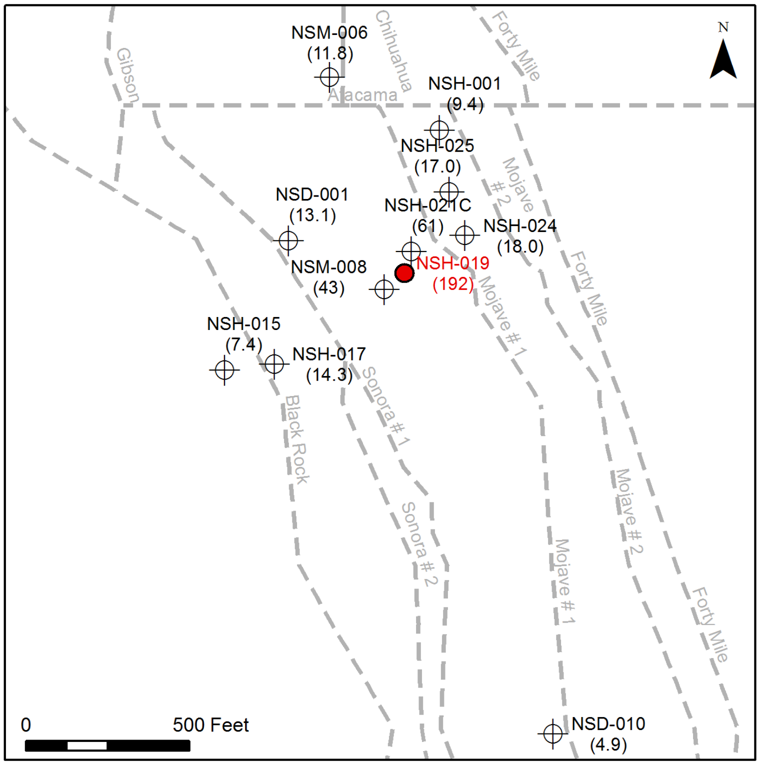


Figure 47

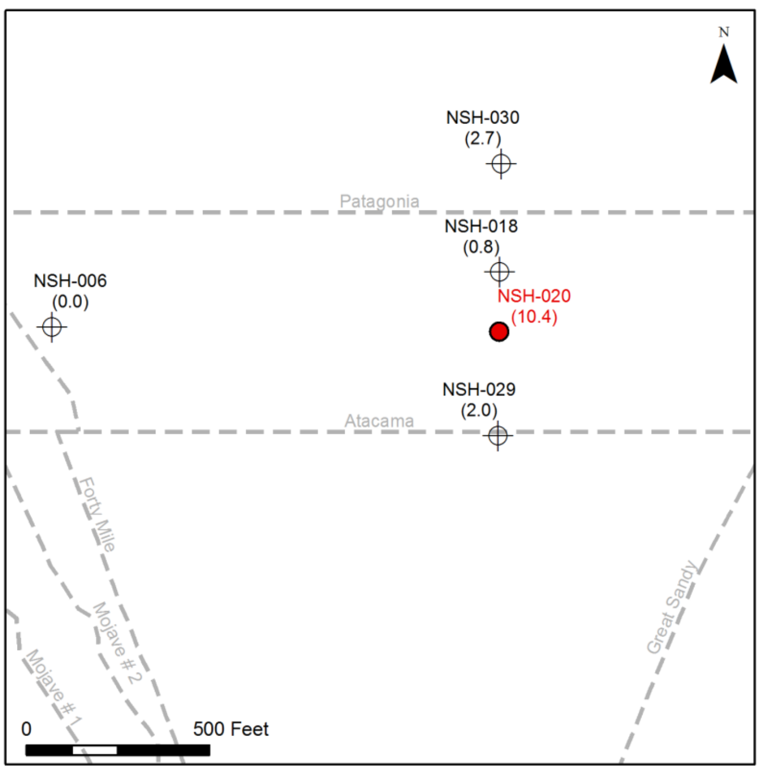


Figure 48

Figure 49

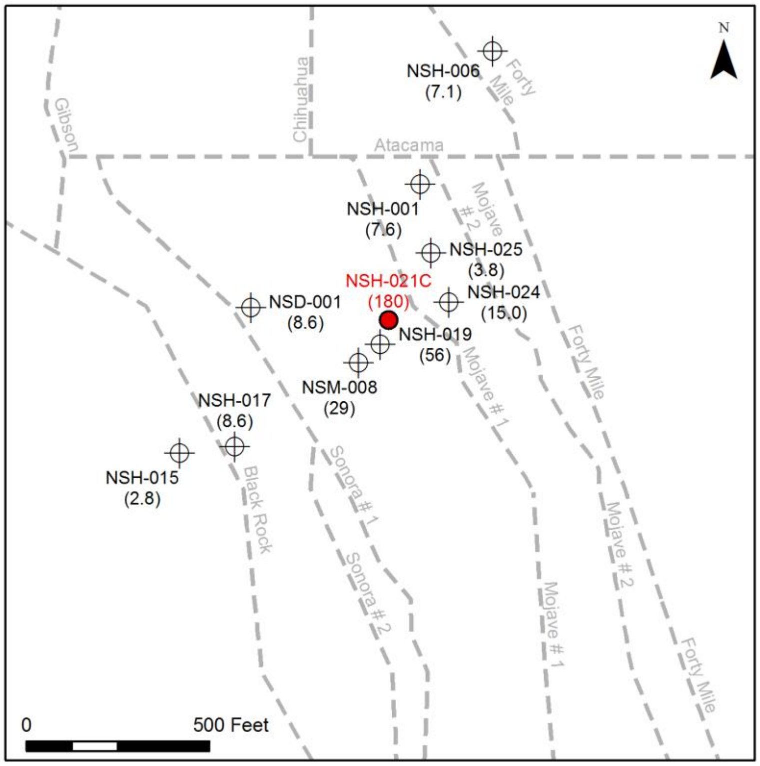


Figure 50

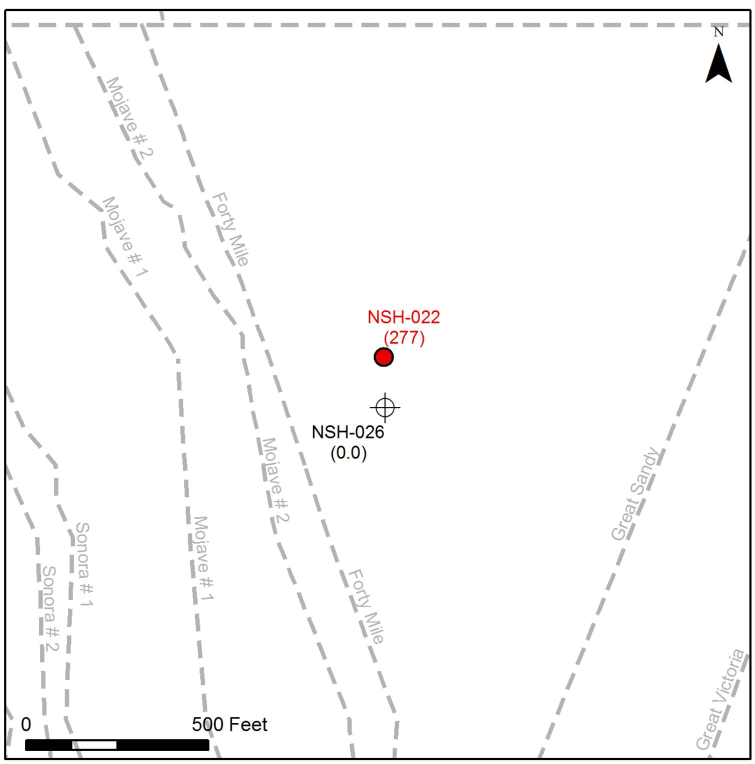


Figure 51

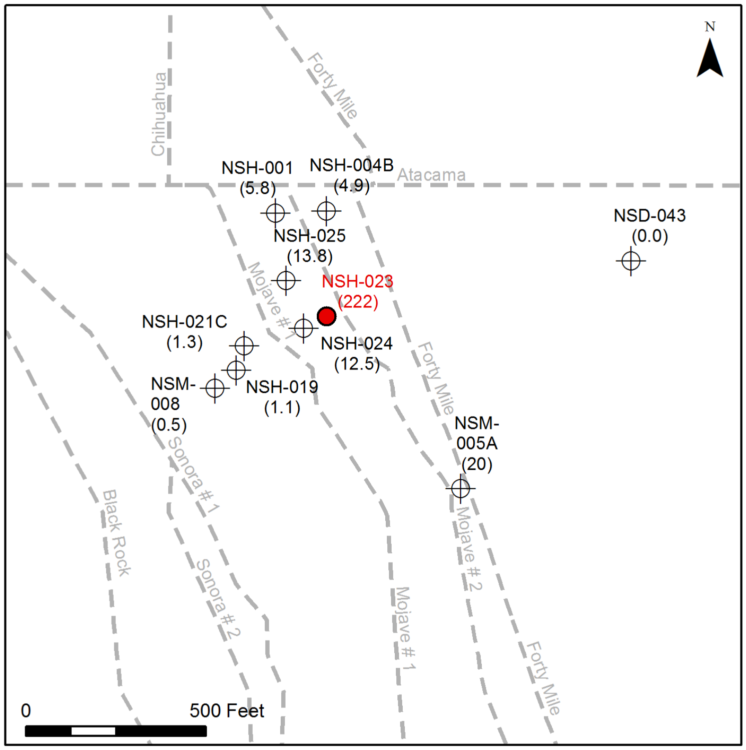
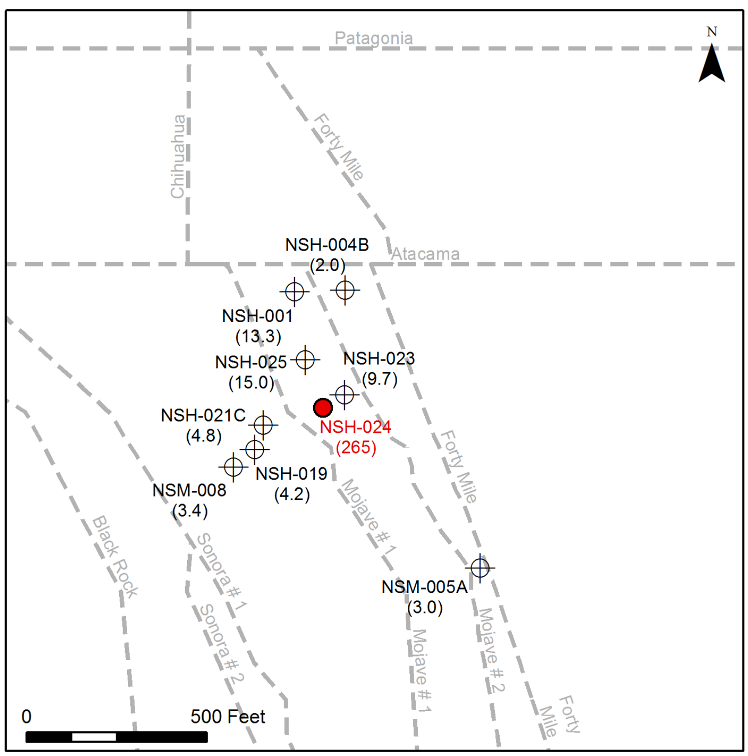


Figure 52



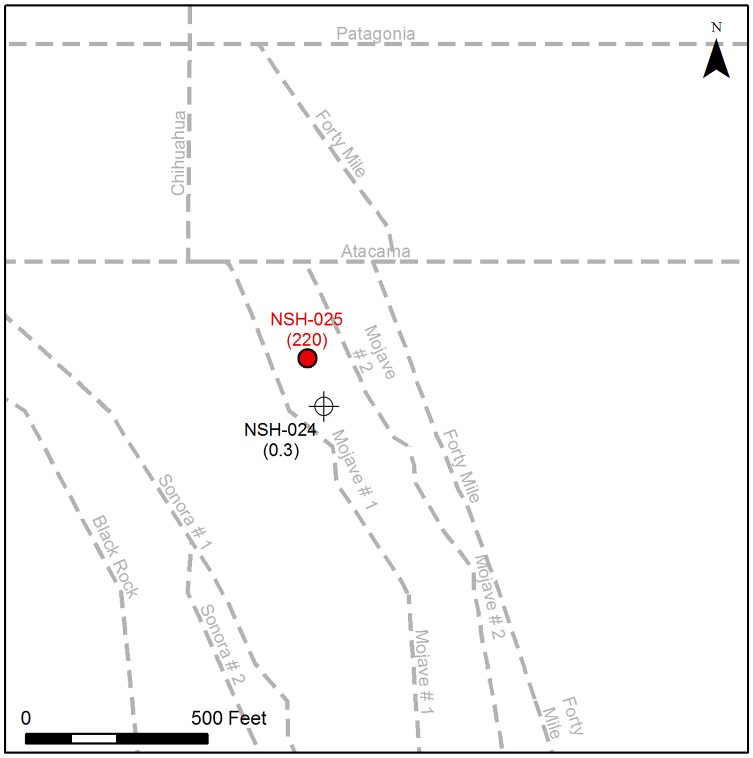


Figure 53

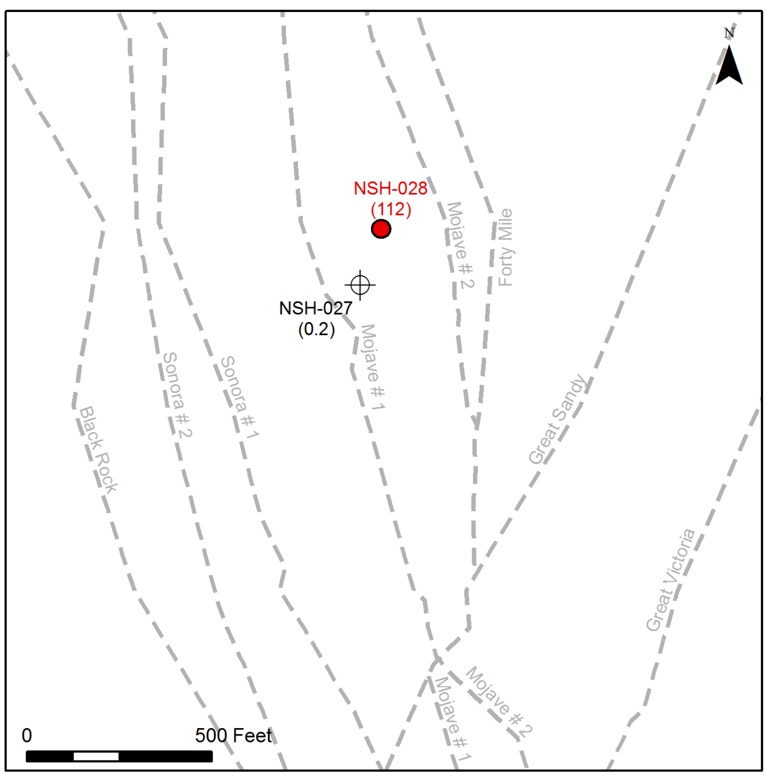


Figure 54

FIGURE 55 through 109.

PUMPTEST ANALYSES

Figure 55

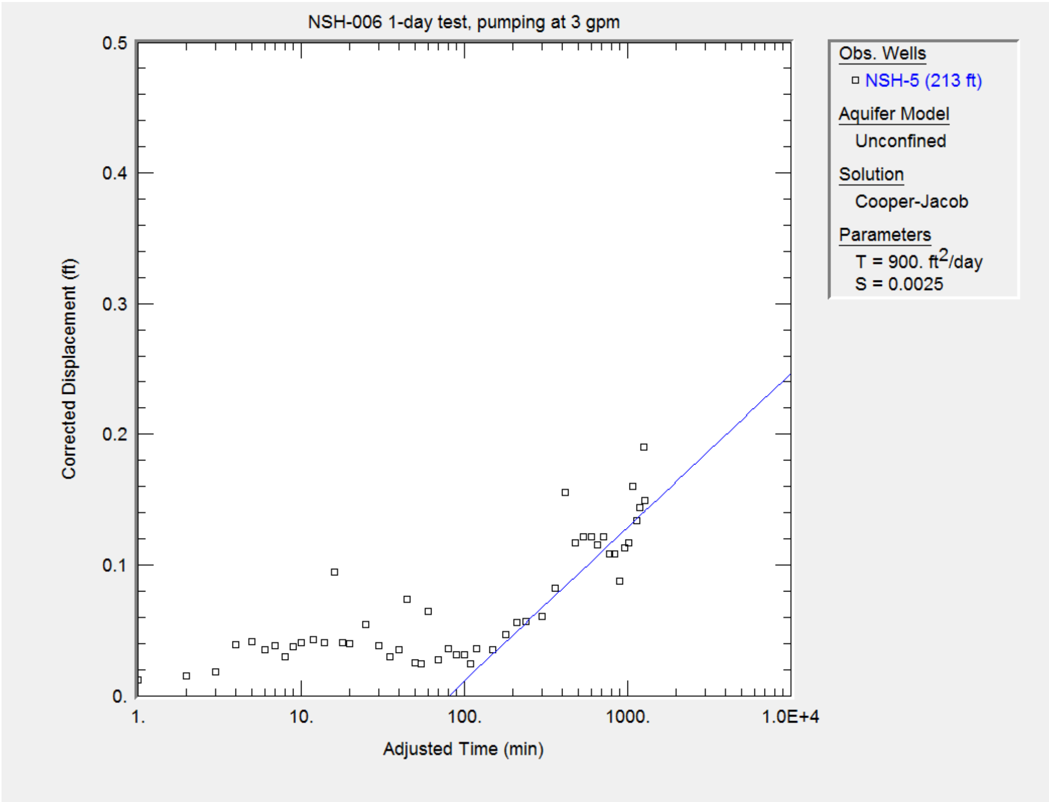


Figure 56

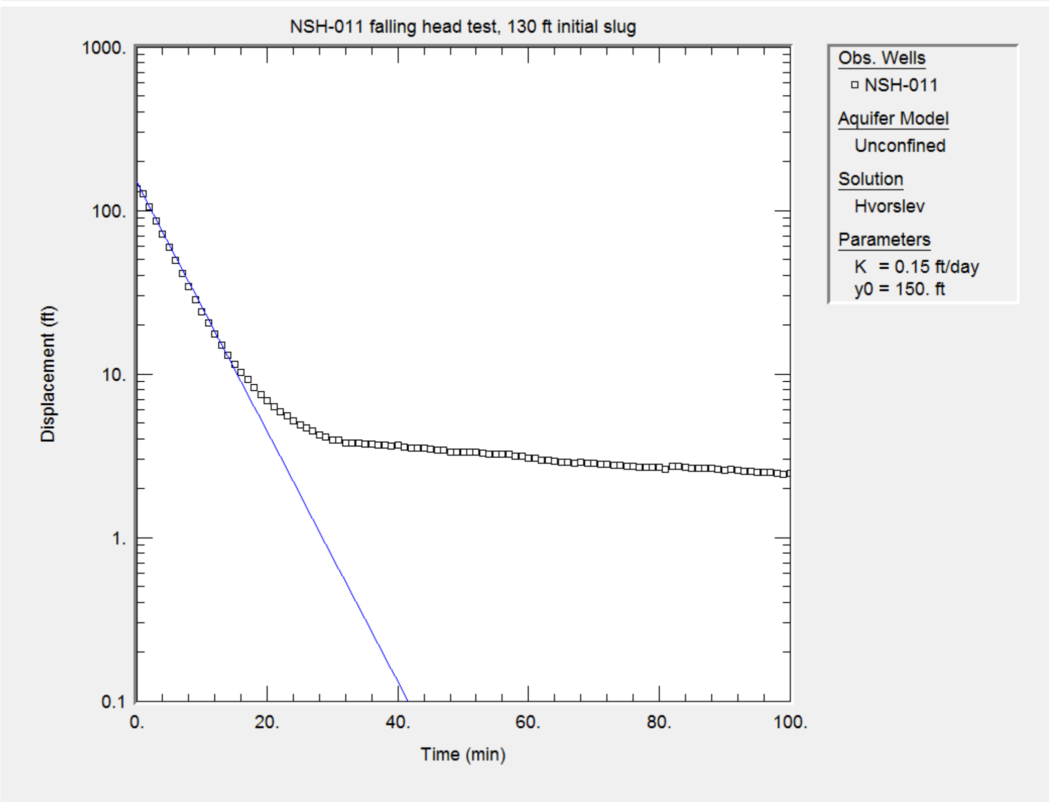


Figure 57

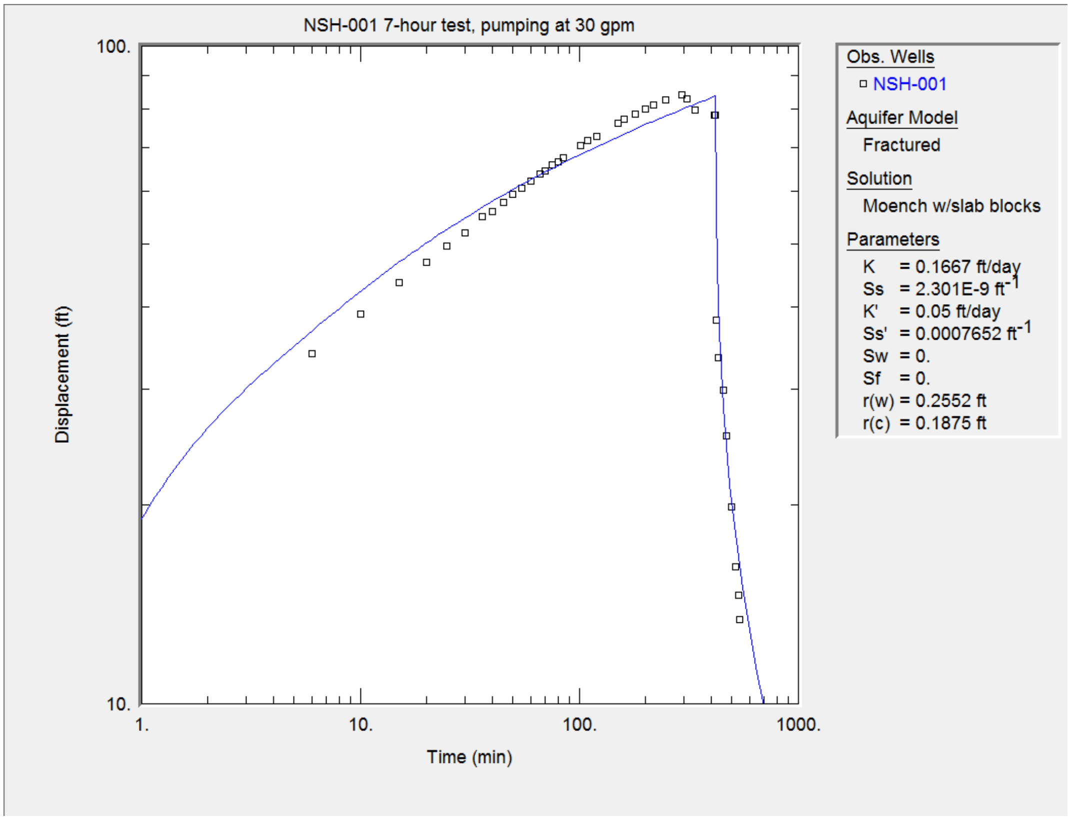


Figure 58

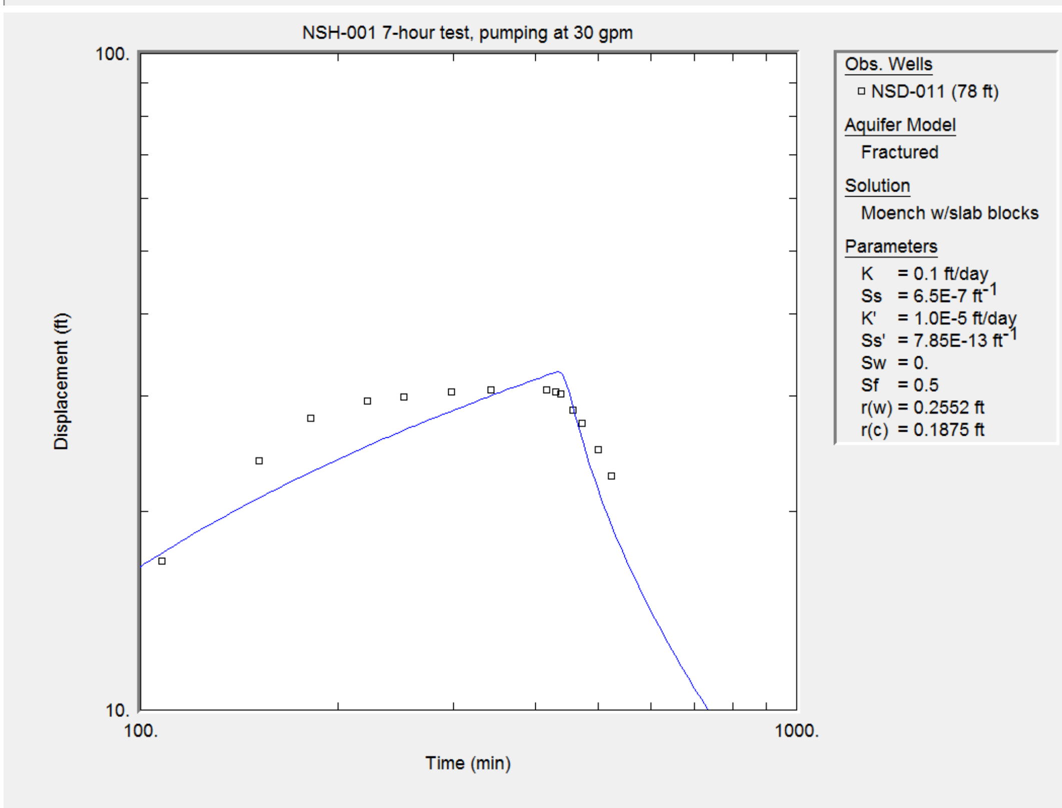


Figure 59

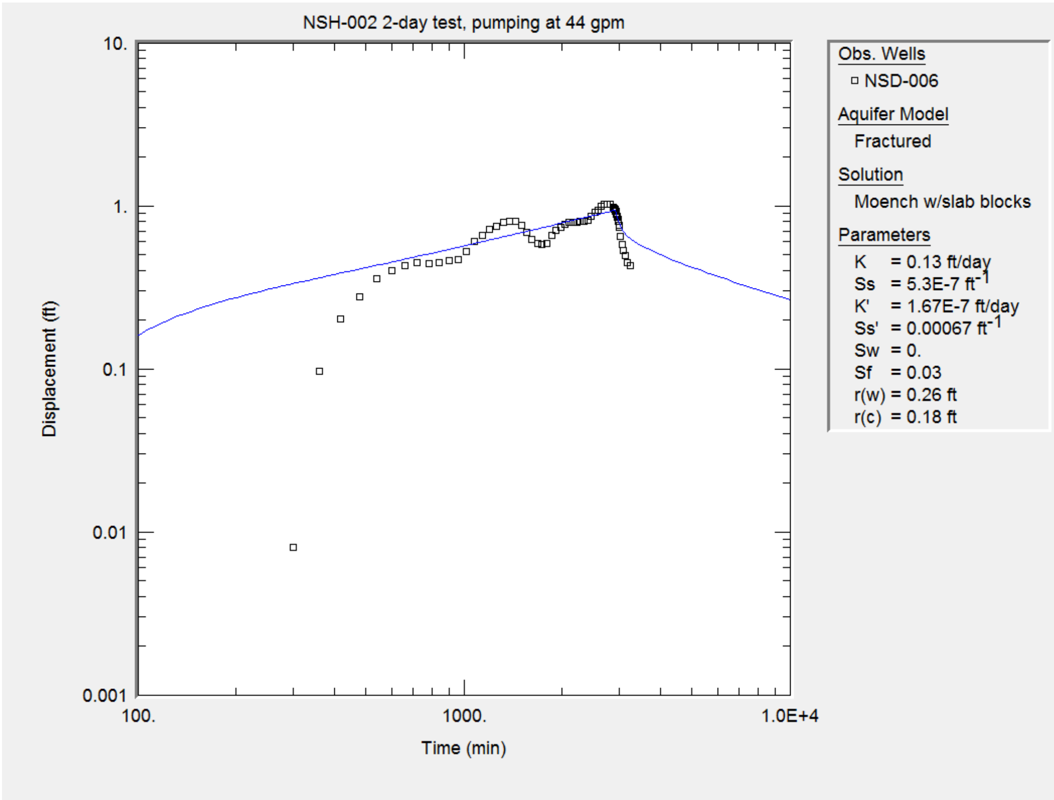


Figure 60

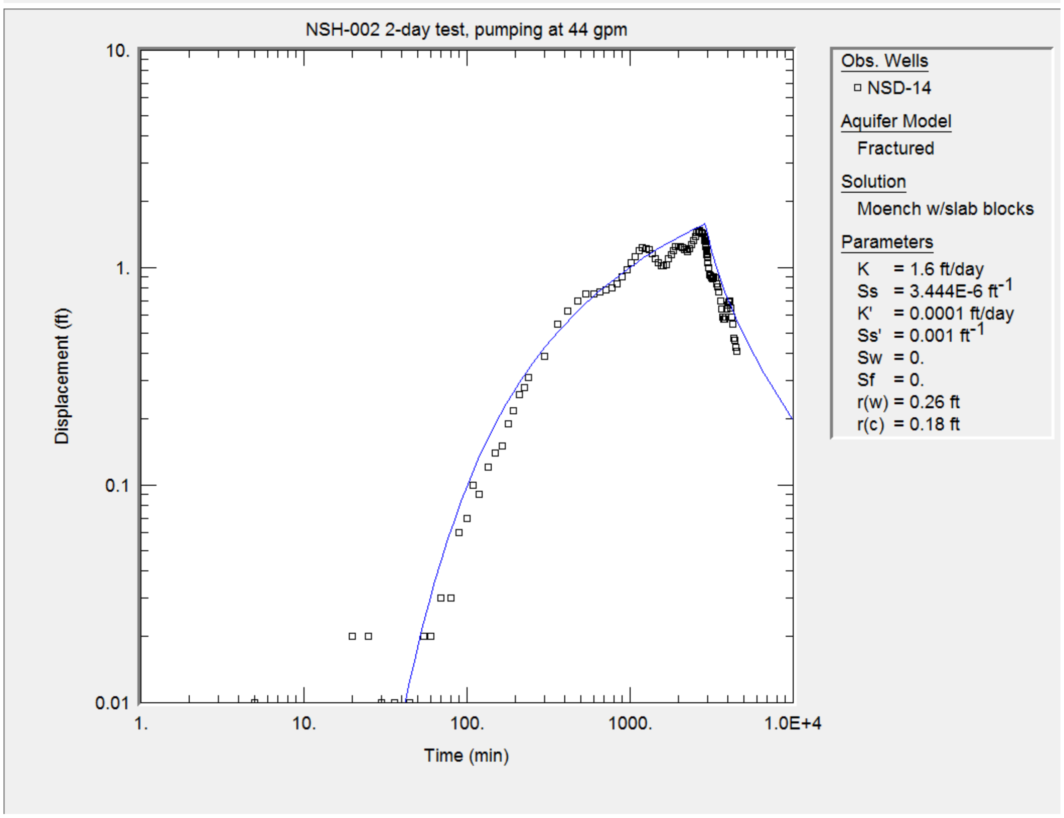
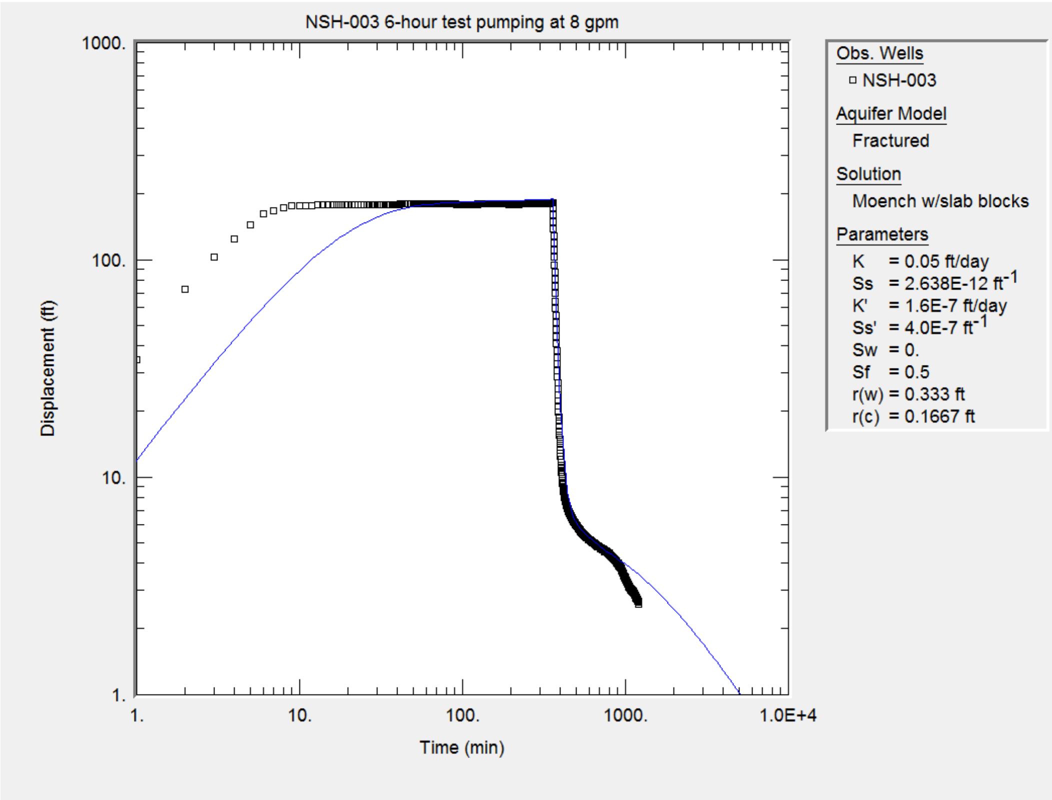


Figure 61



NSH-003 6-hour test pumping at 8 gpm
1000.
100.
10.
1.
Displacement (ft)
1.
10.
100.
1000.
1.0E+4
Time (min)
Obs. Wells
NSH-003
Aquifer Model
Fractured
Solution
Moench w/slab blocks
Parameters
K = 0.05 ft/day
Ss = 2.638E-12 ft-1
K' = 1.6E-7 ft/day
Ss' = 4.0E-7 ft-1
Sw = 0.
Sf = 0.5
r(w) = 0.333 ft
r(c) = 0.1667 ft

Figure 62

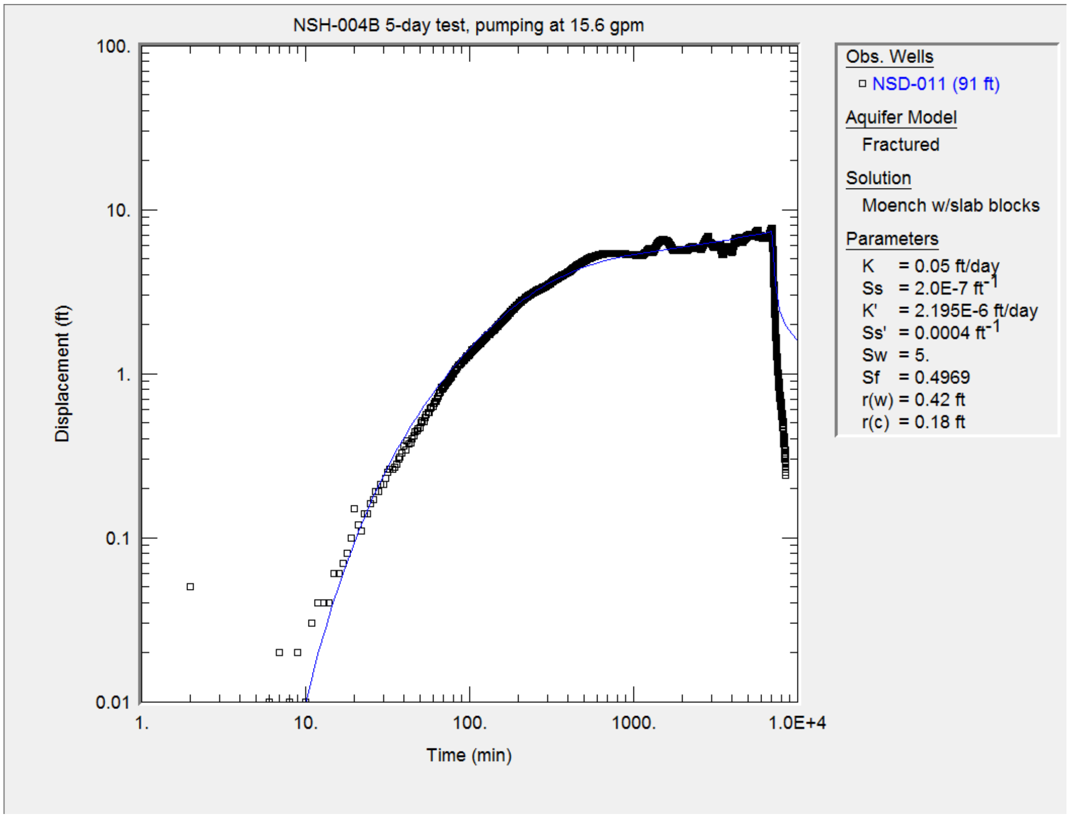


Figure 63

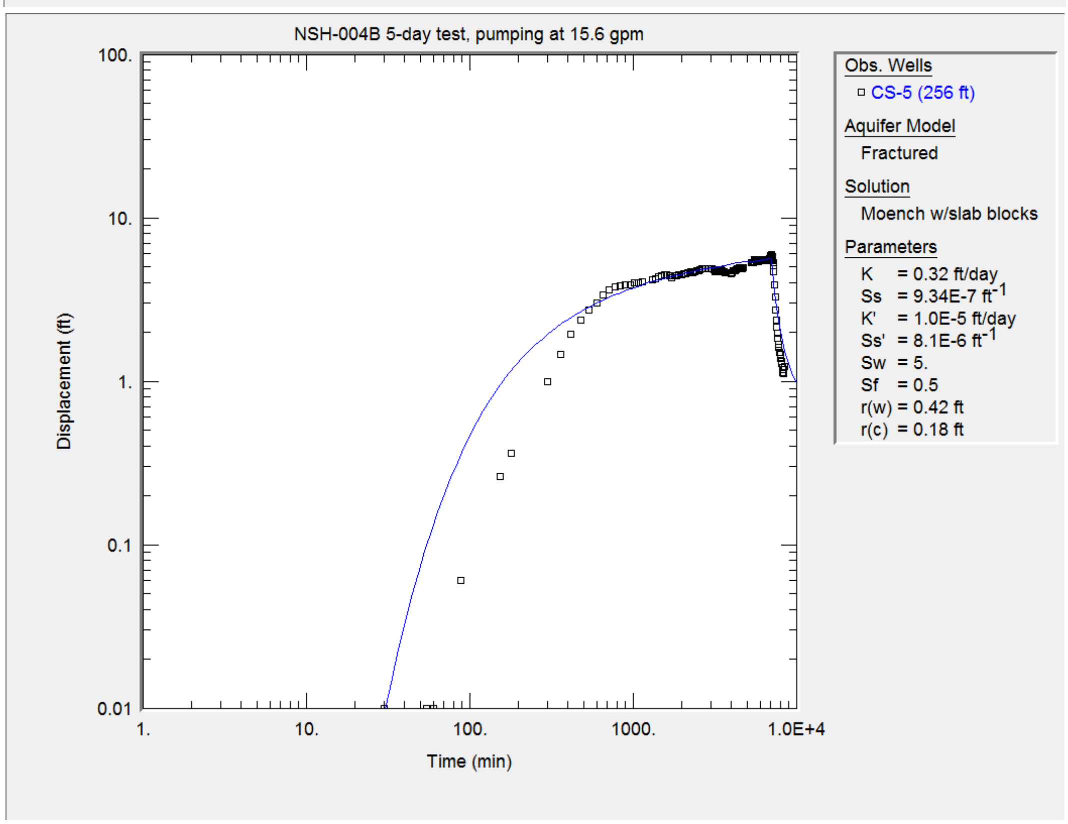


Figure 64

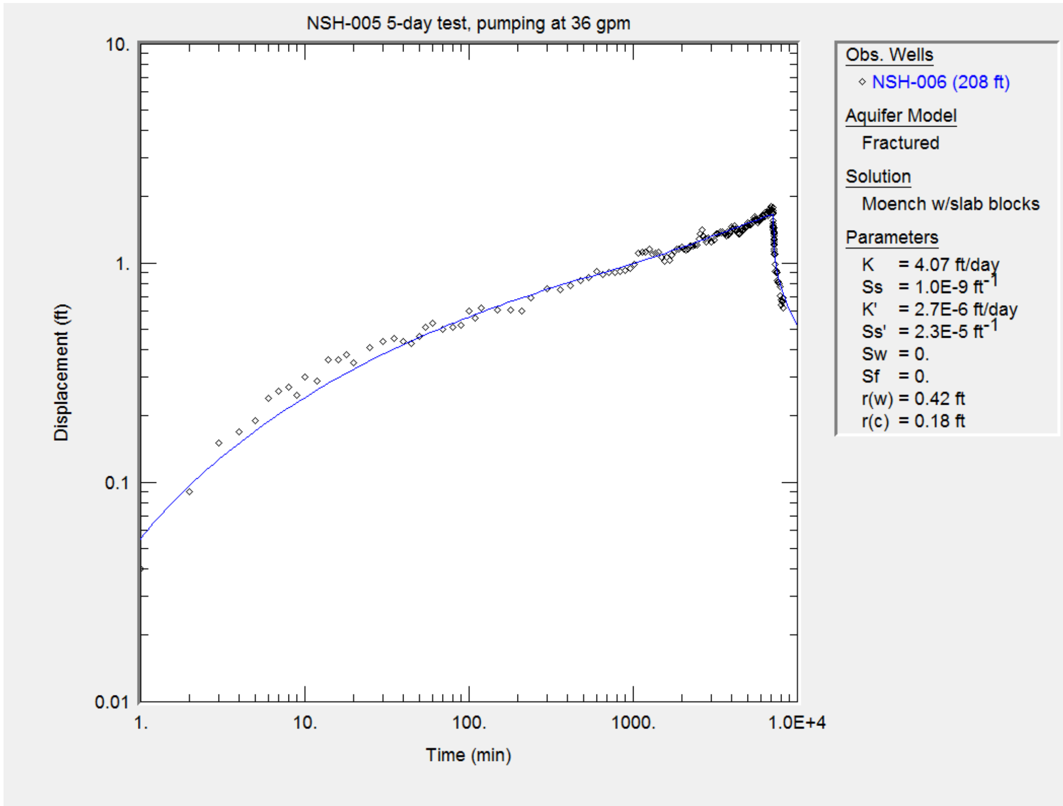


Figure 65

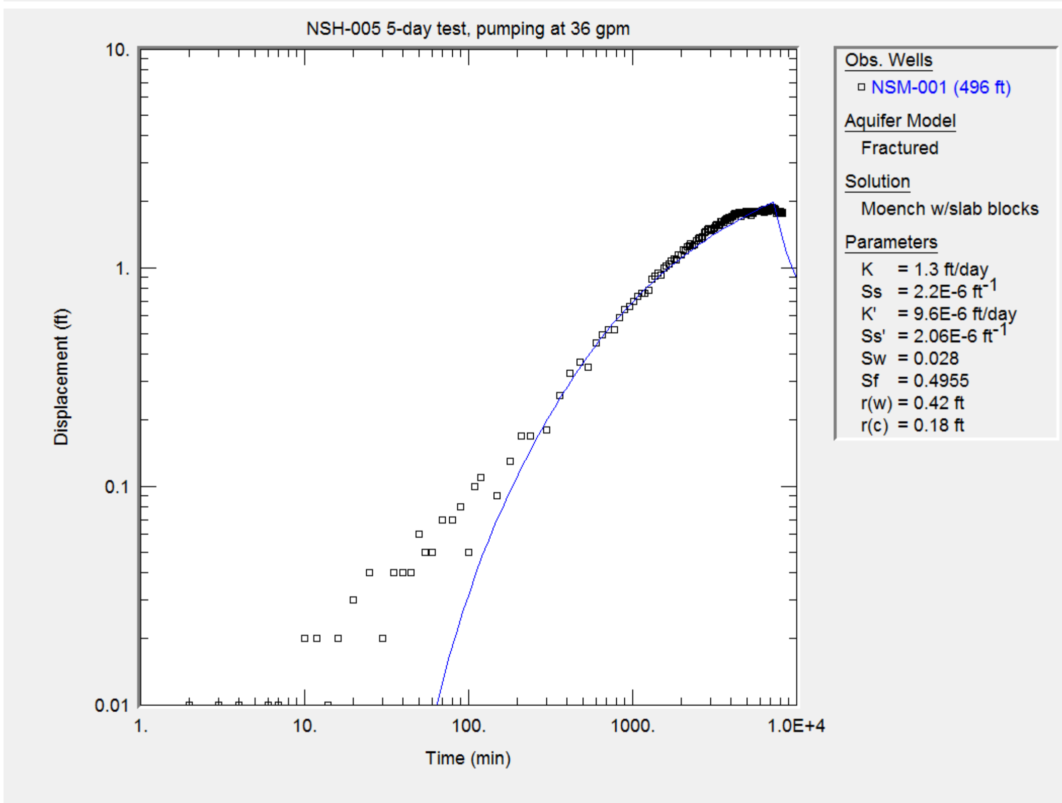


Figure 66

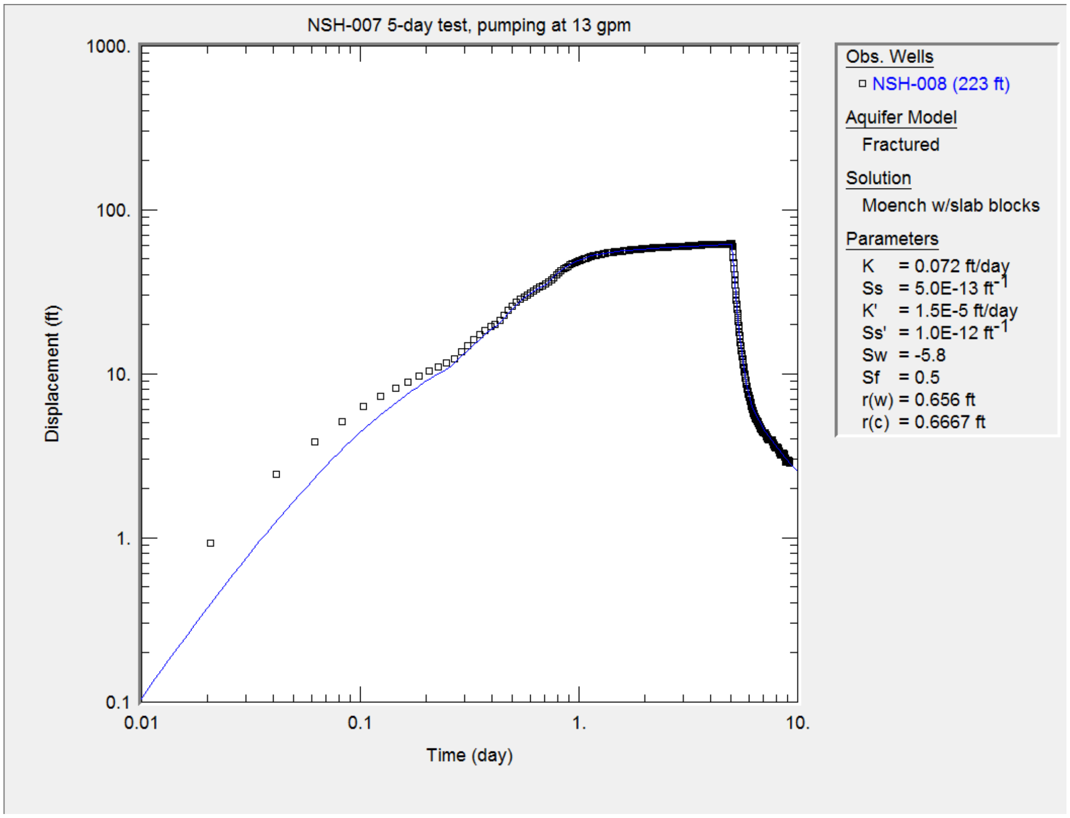


Figure 67

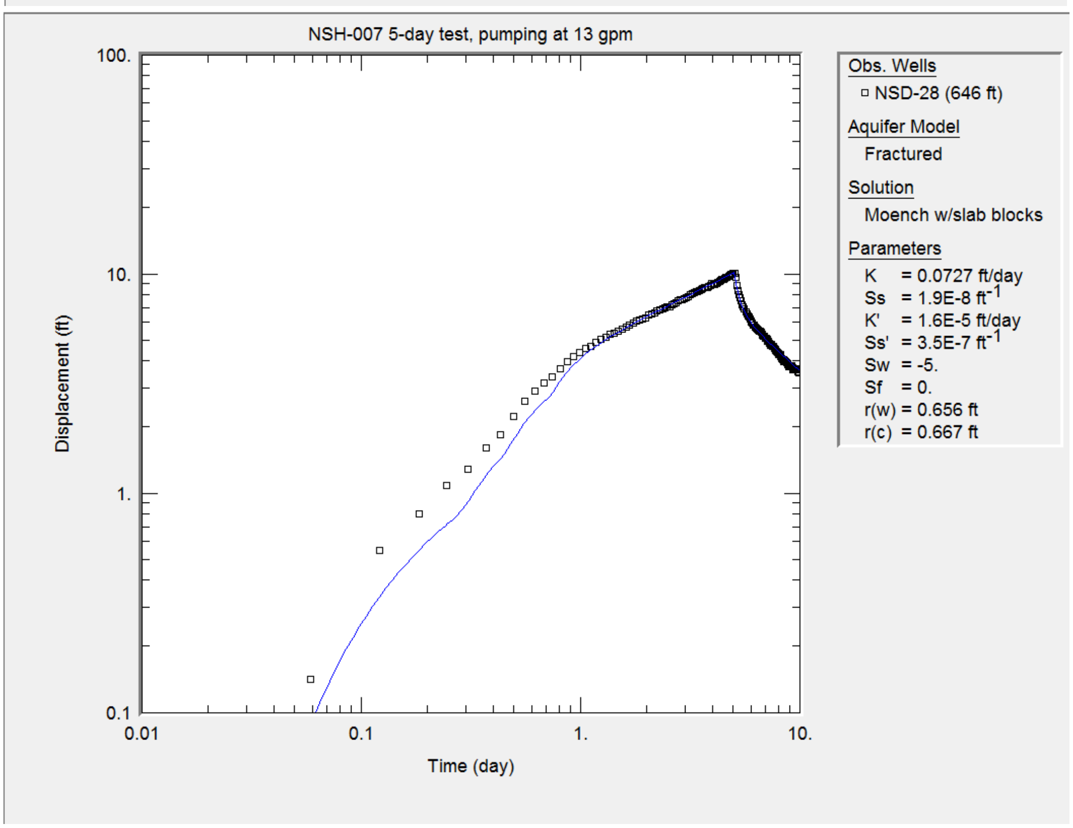
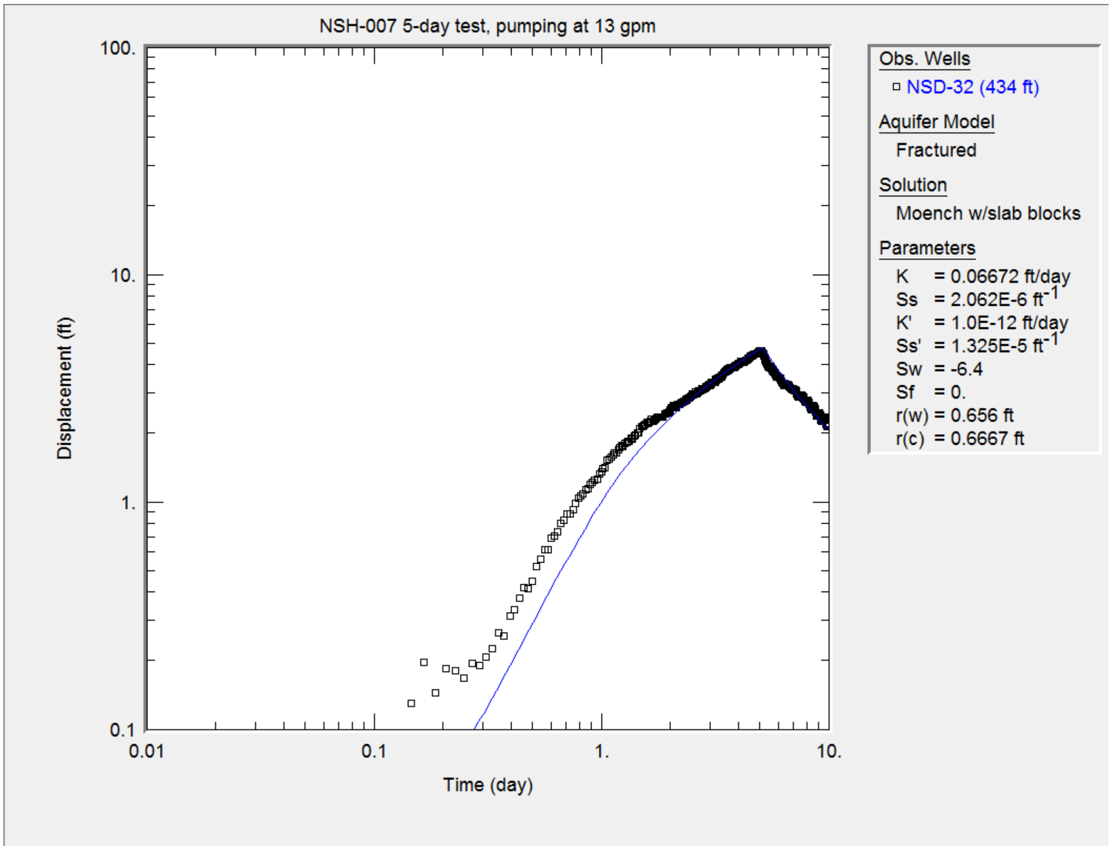


Figure 68



NSH-007 5-day test, pumping at 13 gpm
Displacement (ft)
Time (day)
100.
10.
1.
0.1
0.01
0.1
1.
10.
Obs. Wells
NSD-32 (434 ft)
Aquifer Model
Fractured
Solution
Moench w/slab blocks
Parameters
K = 0.06672 ft/day
Ss = 2.062E-6 ft-1
K' = 1.0E-12 ft/day
Ss' = 1.325E-5 ft-1
Sw = -6.4
Sf = 0.
r(w) = 0.656 ft
r(c) = 0.6667 ft

Figure 69

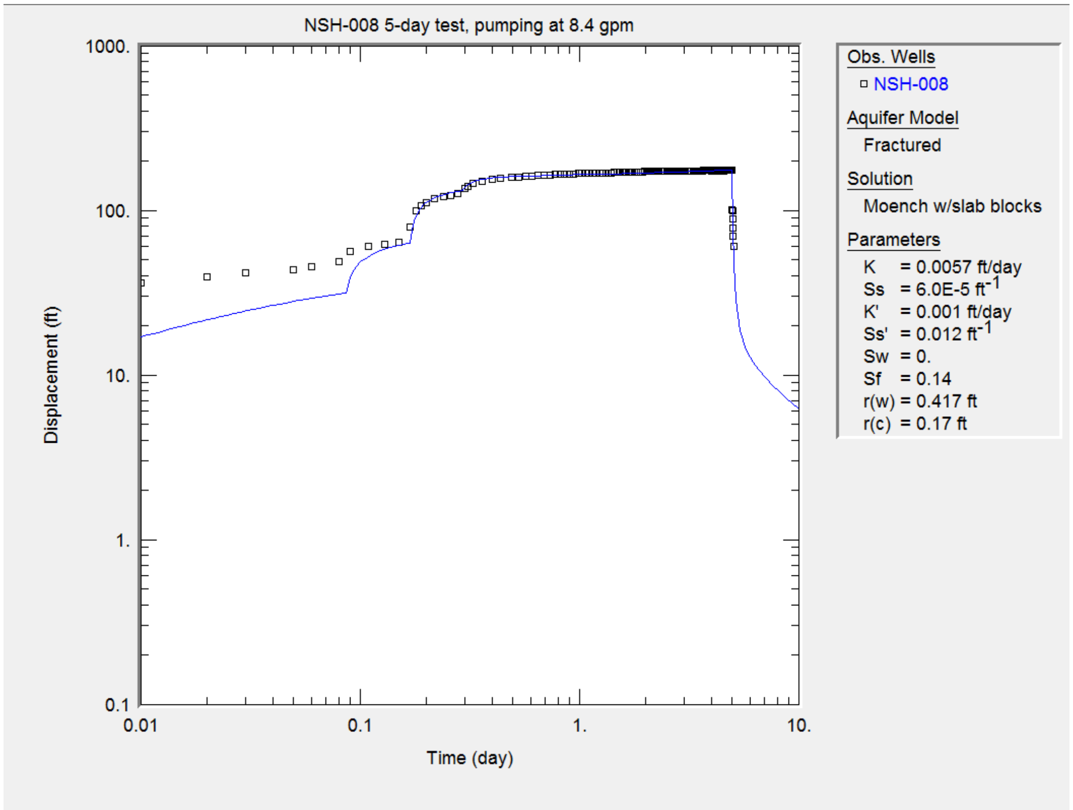


Figure 70

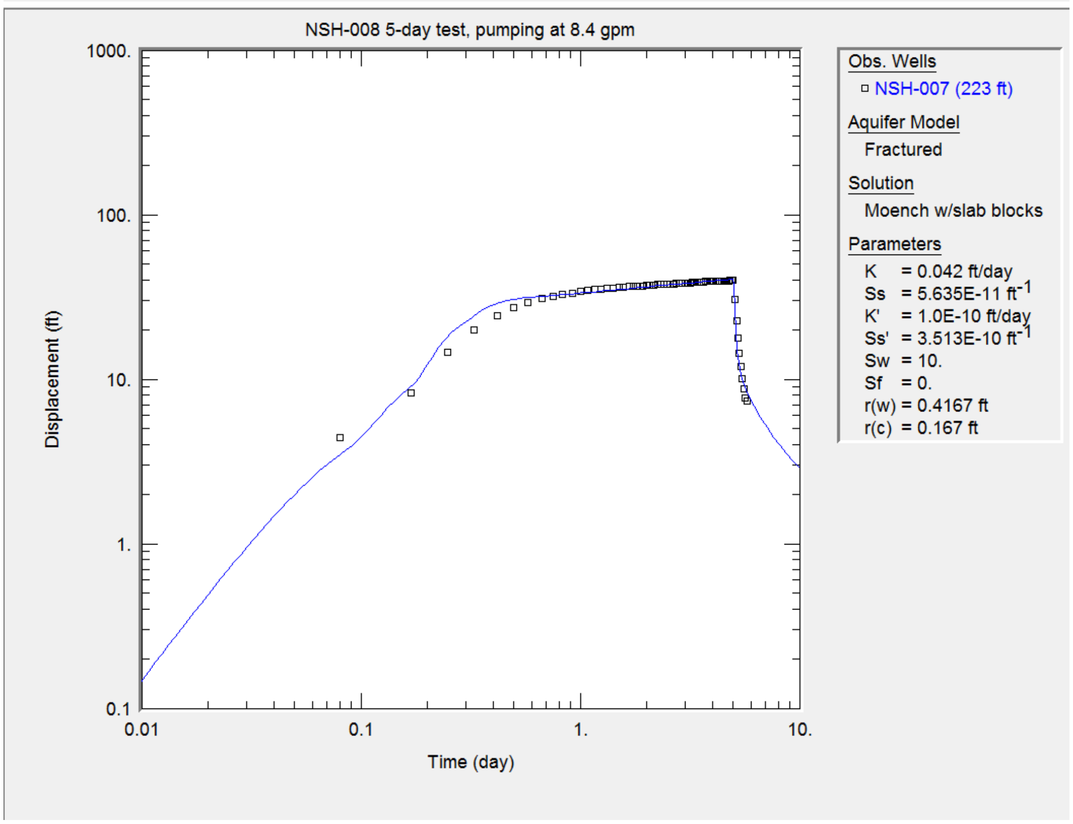


Figure 71

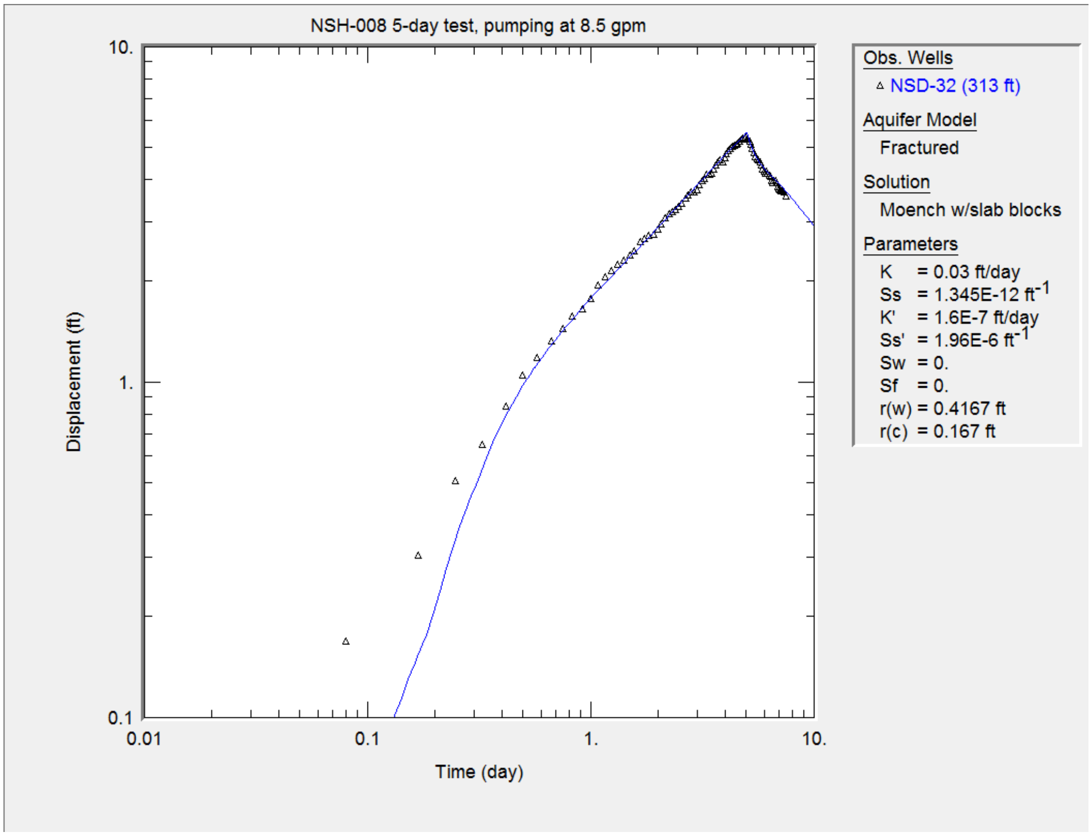

NSH-008 5-day test, pumping at 8.5 gpm
Displacement (ft)
10.
1.
0.1
0.01
0.1
1.
10.
Time (day)
Obs. Wells
NSD-32 (313 ft)
Aquifer Model
Fractured
Solution
Moench w/slab blocks
Parameters
K = 0.03 ft/day
Ss = 1.345E-12 ft-1
K' = 1.6E-7 ft/day
Ss' = 1.96E-6 ft-1
Sw = 0.
Sf = 0.
r(w) = 0.4167 ft
r(c) = 0.167 ft

Figure 72

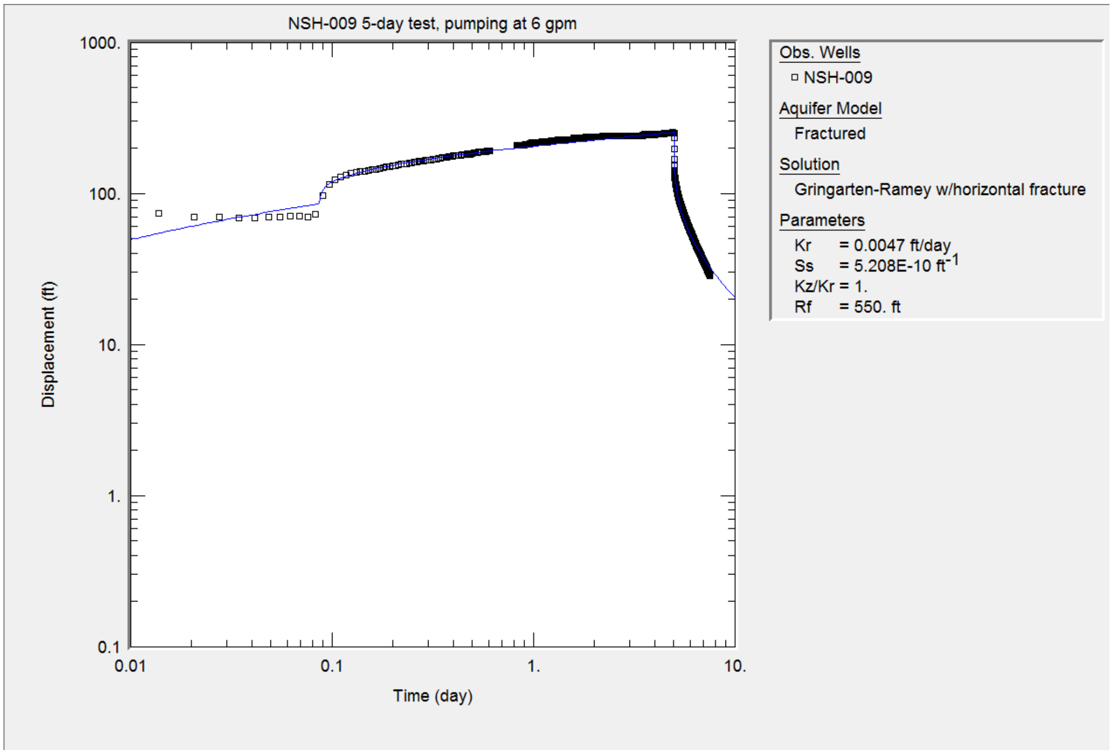


Figure 73

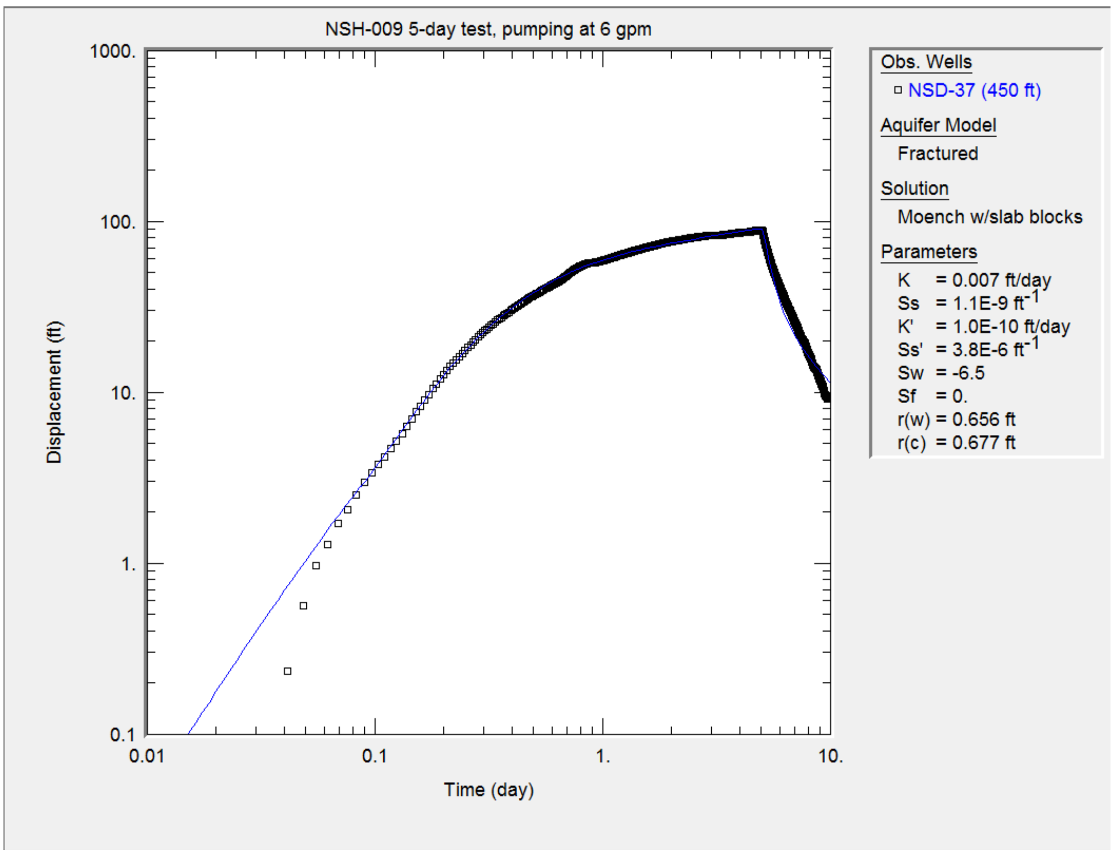


Figure 74

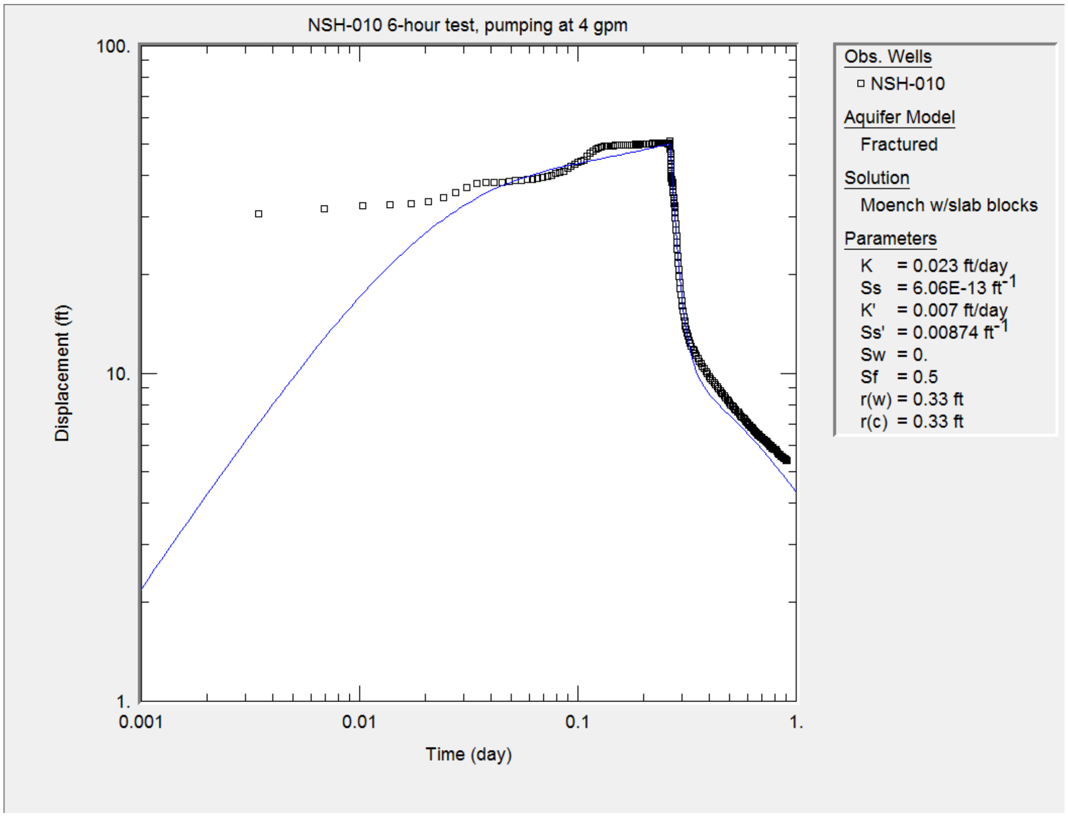


Figure 75

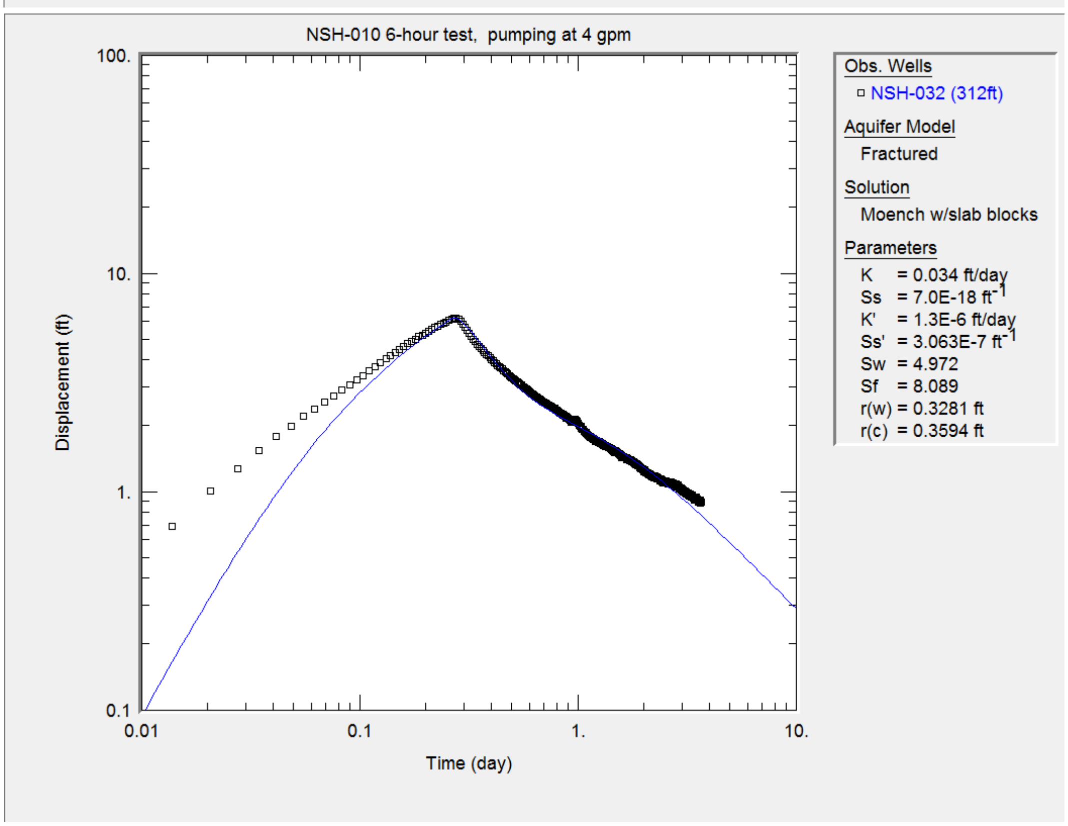


Figure 76

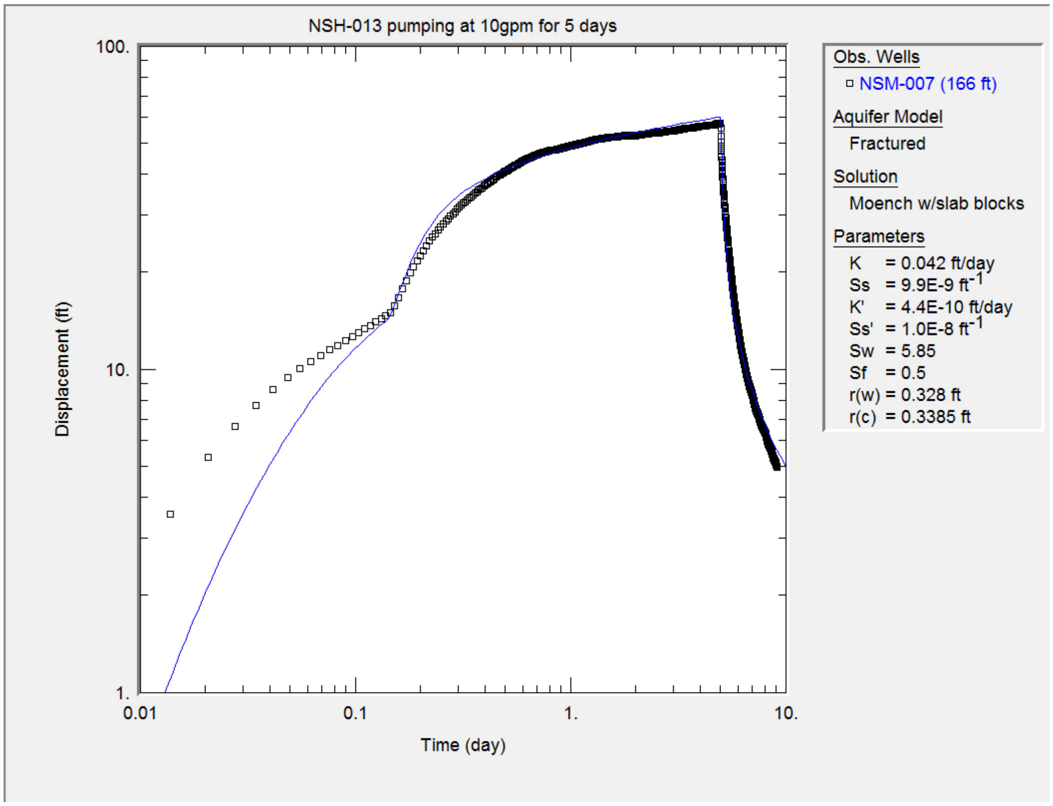


Figure 77

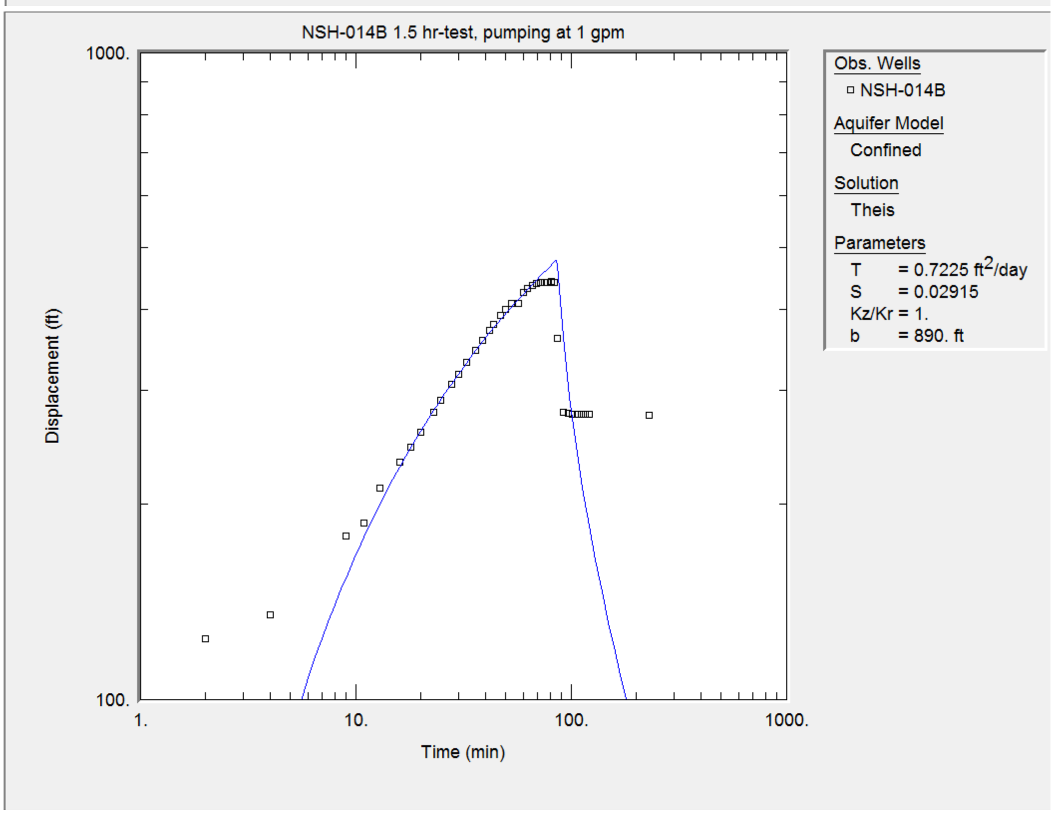


Figure 78

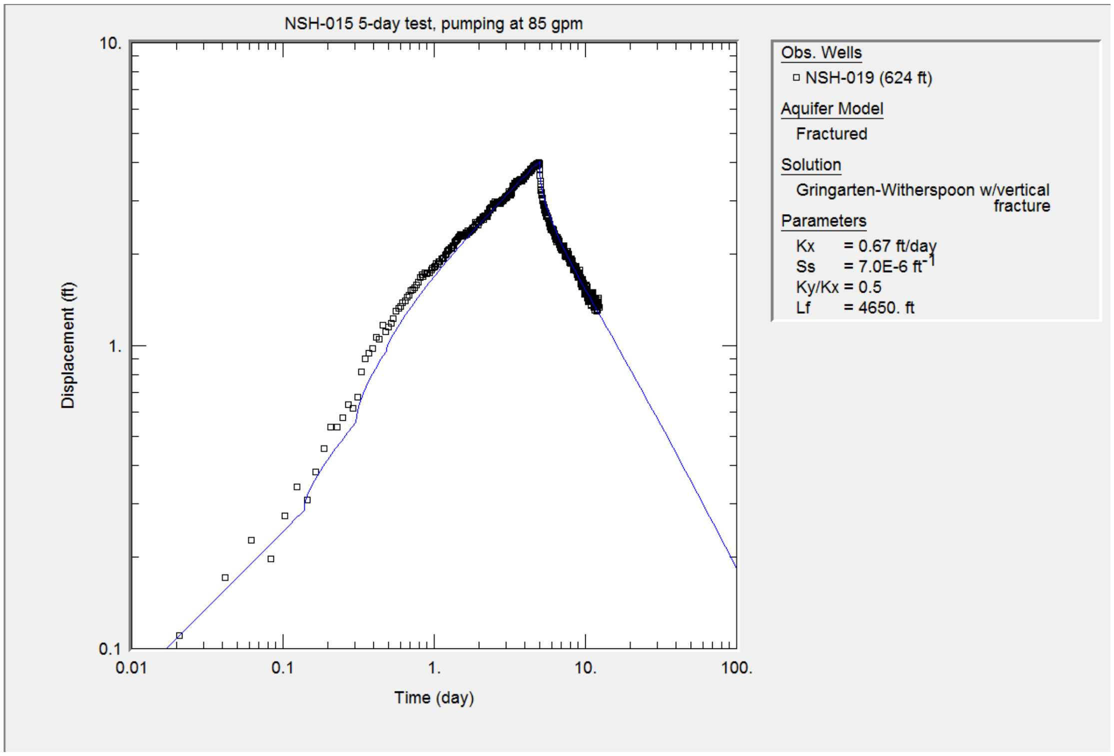


Figure 79

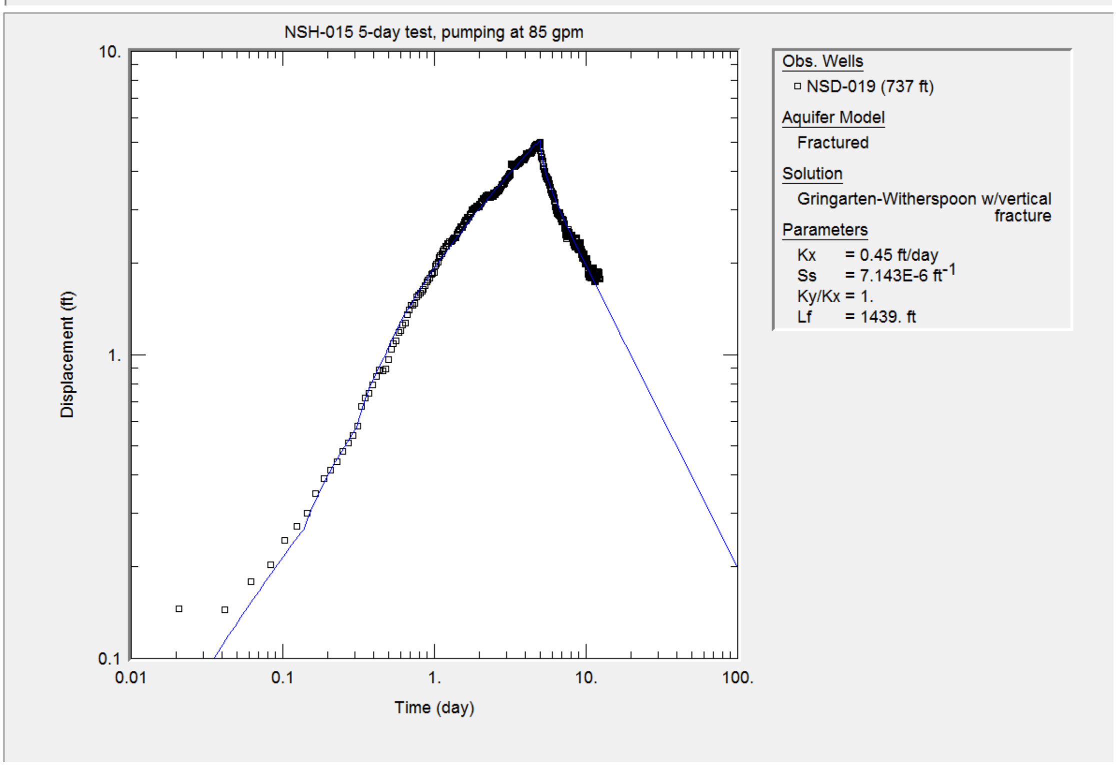


Figure 80

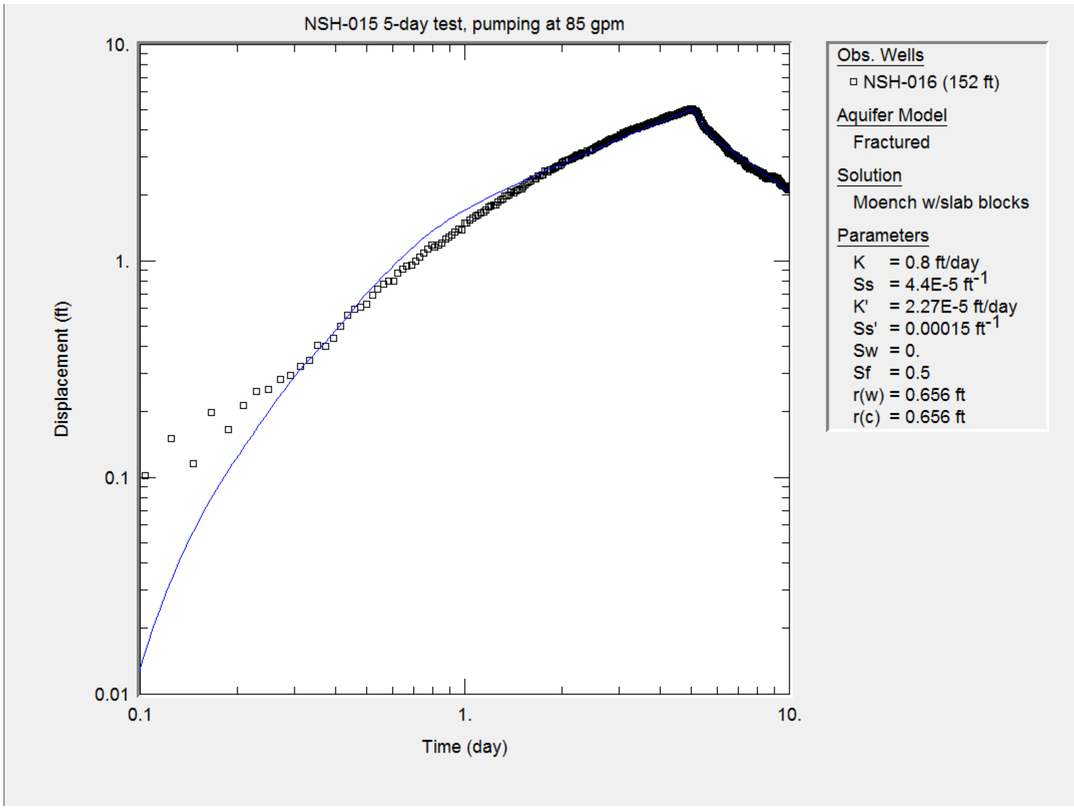


Figure 81

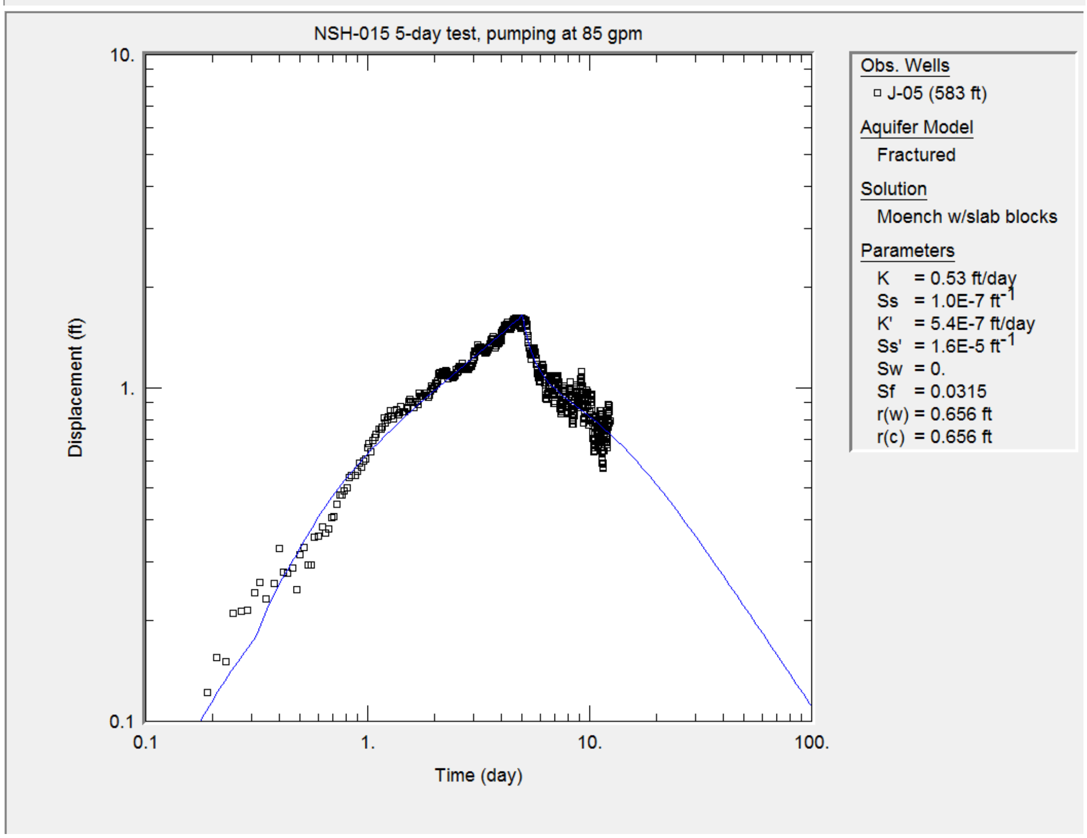


Figure 82

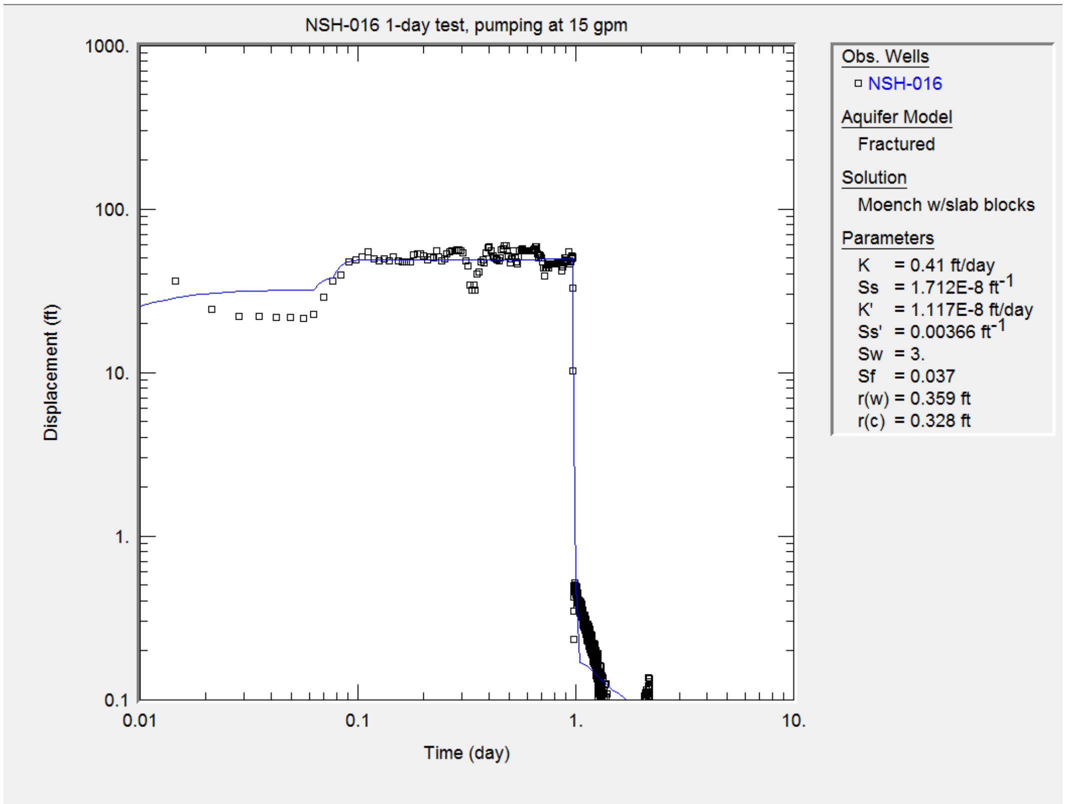


Figure 83

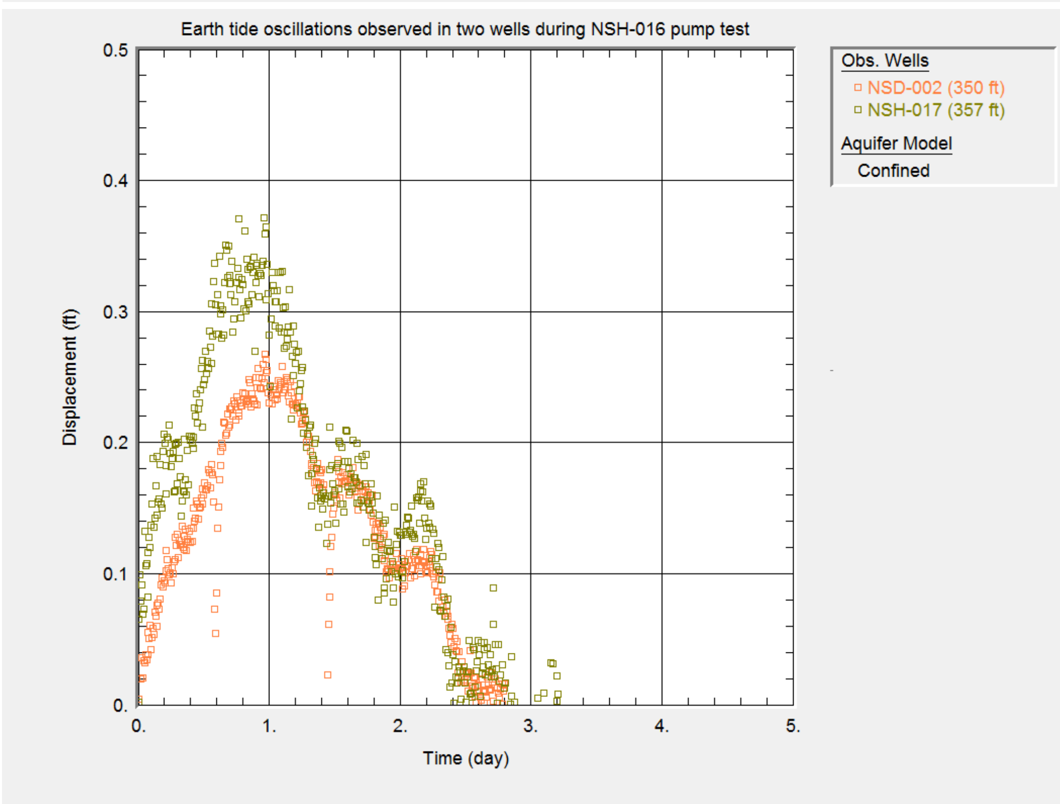


Figure 84

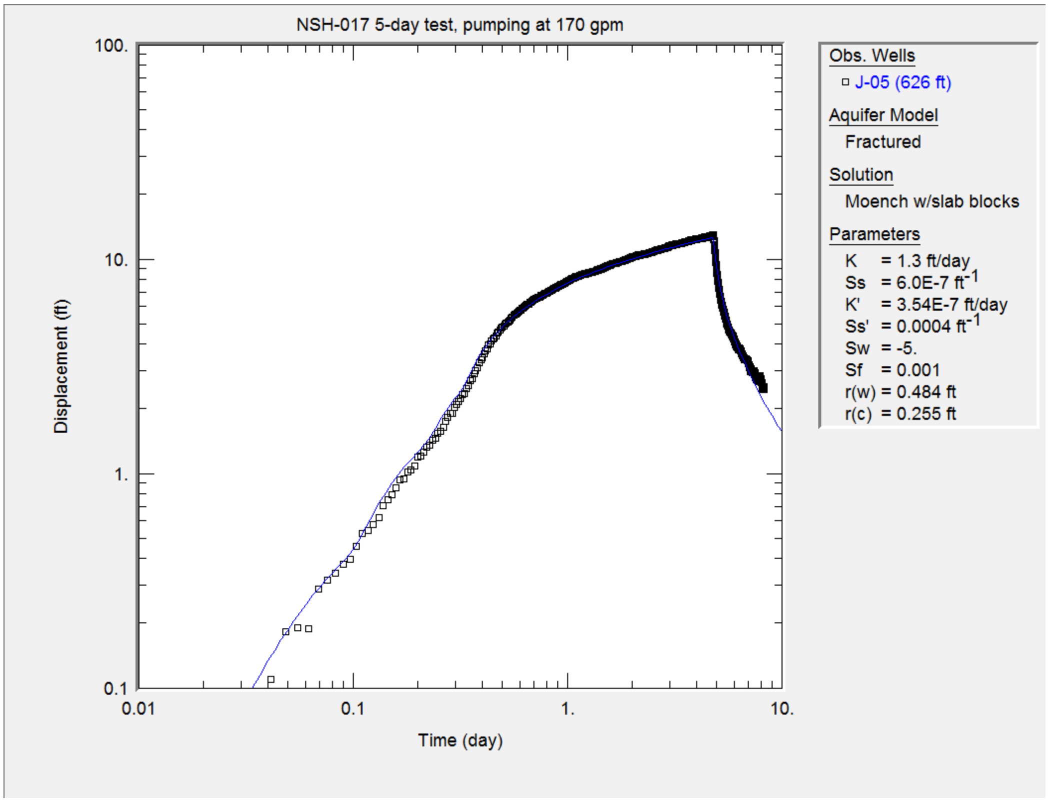


Figure 85

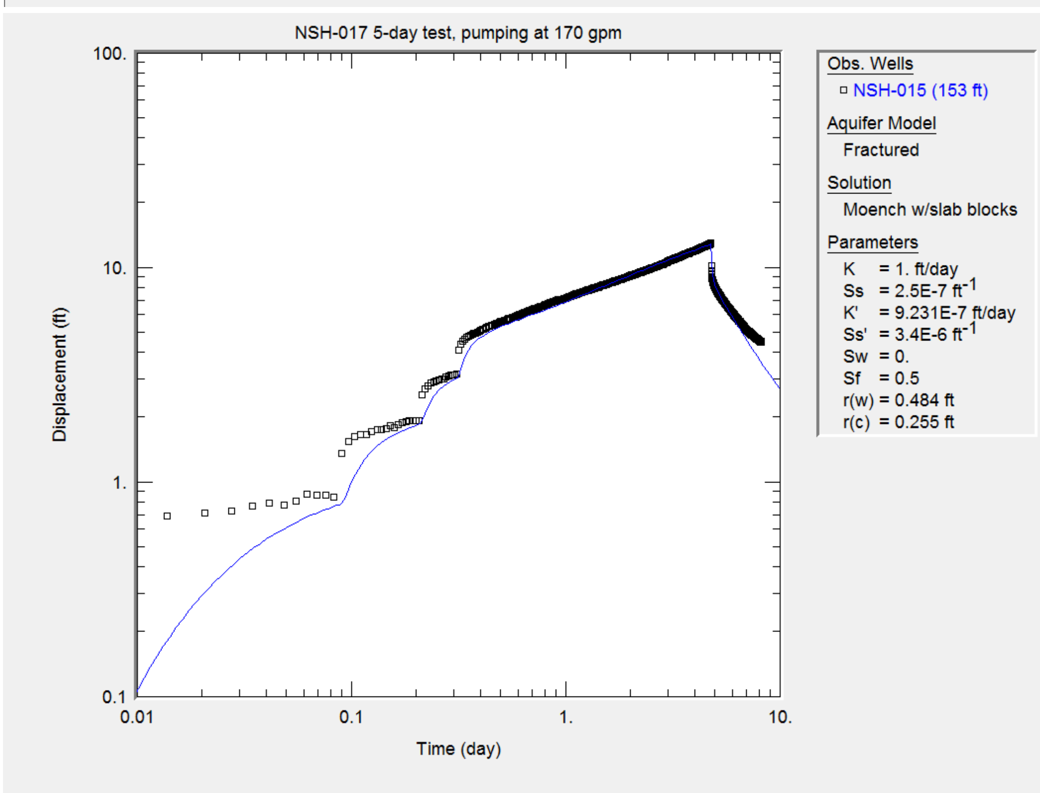


Figure 86

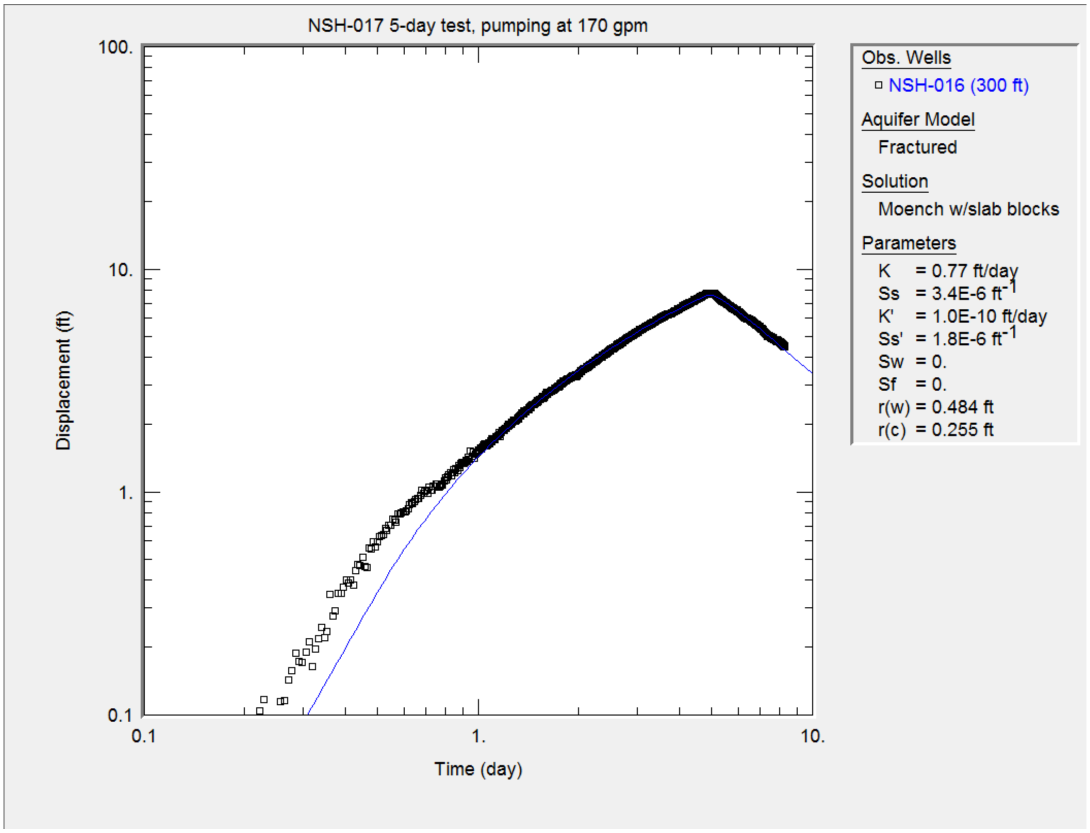

NSH-017 5-day test, pumping at 170 gpm
Displacement (ft)
100.
10.
1.
0.1
0.1
1.
10.
Time (day)
Obs. Wells
NSH-016 (300 ft)
Aquifer Model
Fractured
Solution
Moench w/slab blocks
Parameters
K = 0.77 ft/day
Ss = 3.4E-6 ft^-1
K' = 1.0E-10 ft/day
Ss' = 1.8E-6 ft^-1
Sw = 0.
Sf = 0.
r(w) = 0.484 ft
r(c) = 0.255 ft

Figure 87

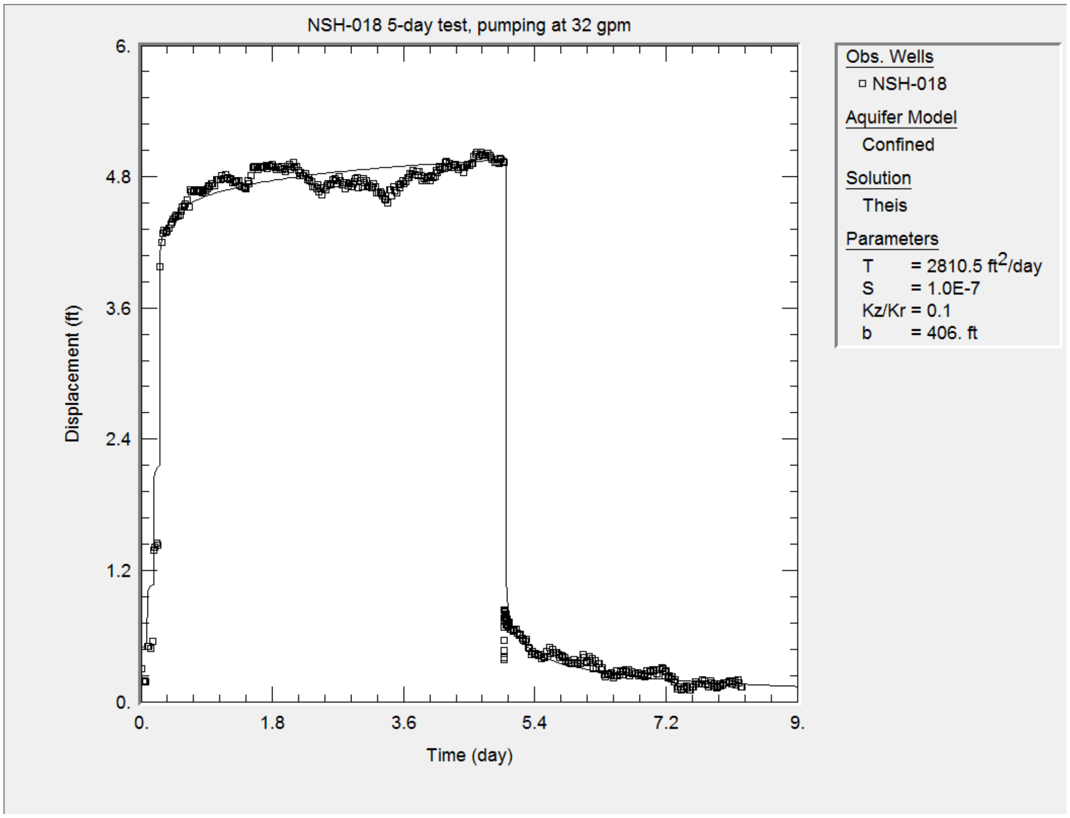


Figure 88

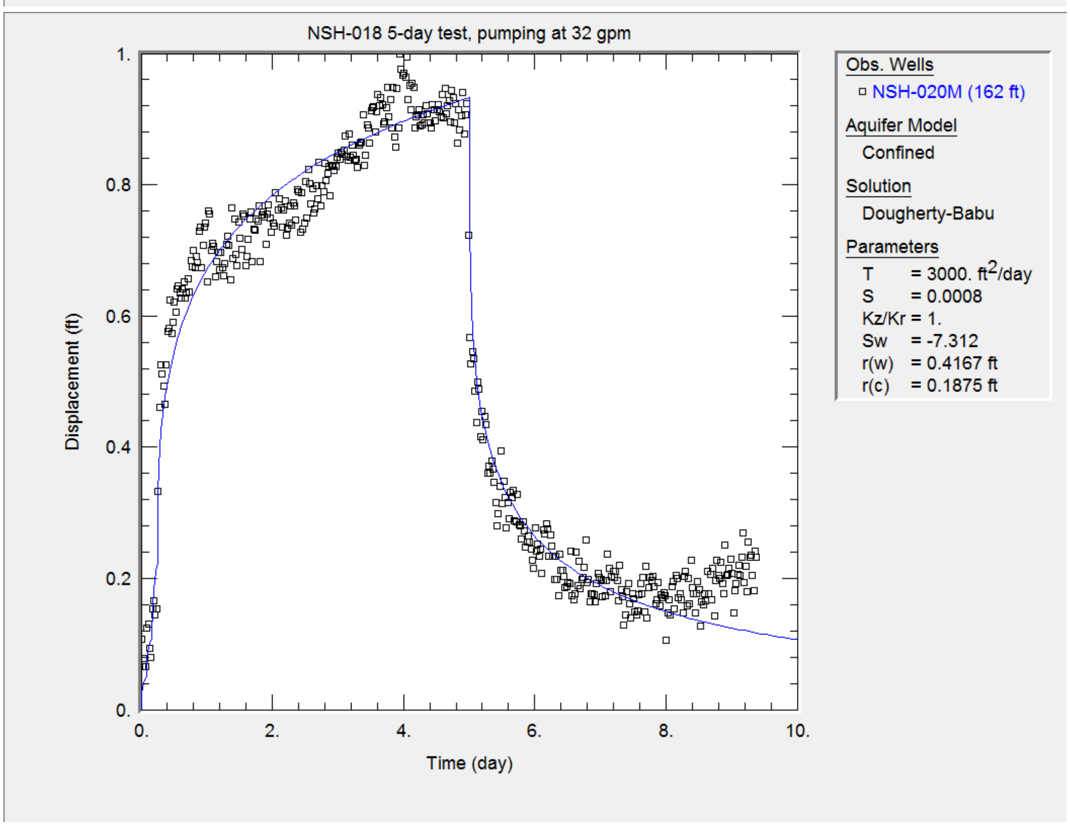


Figure 89

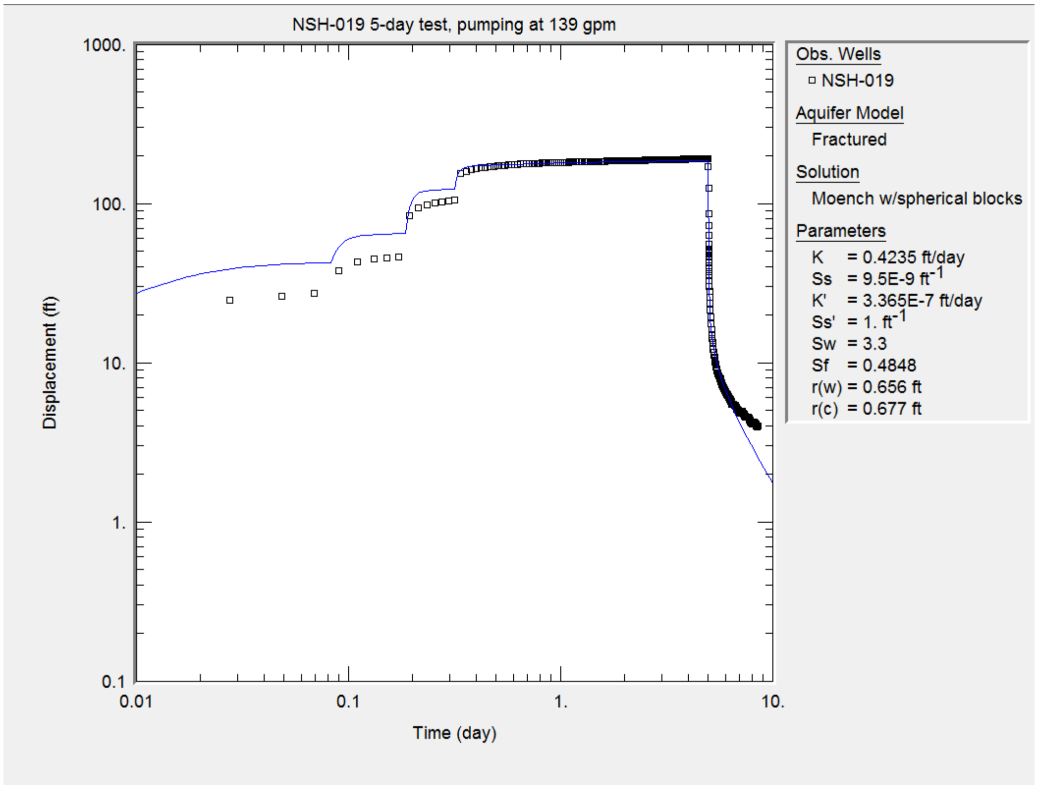


Figure 90

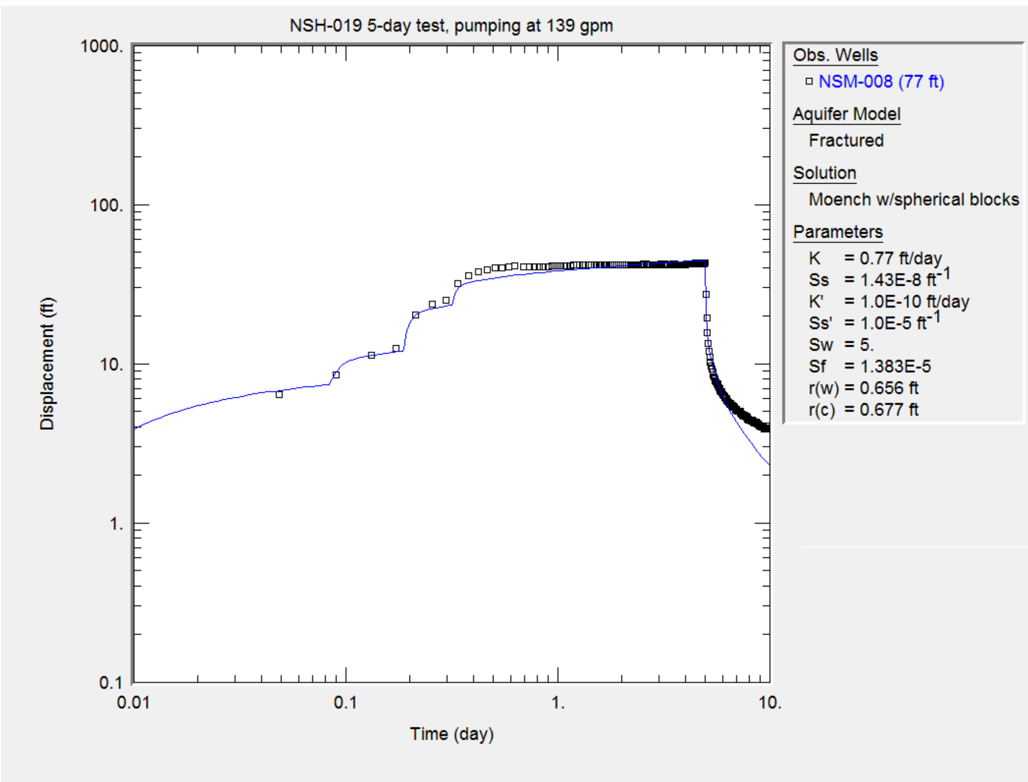


Figure 91

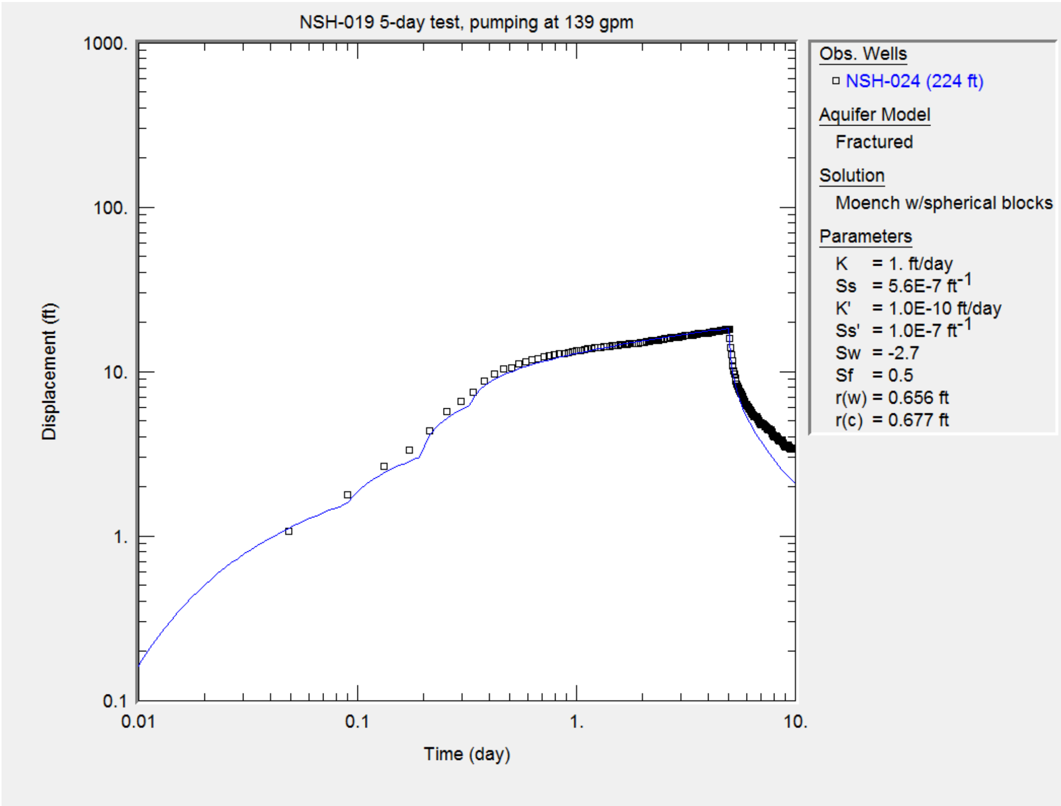


Figure 92

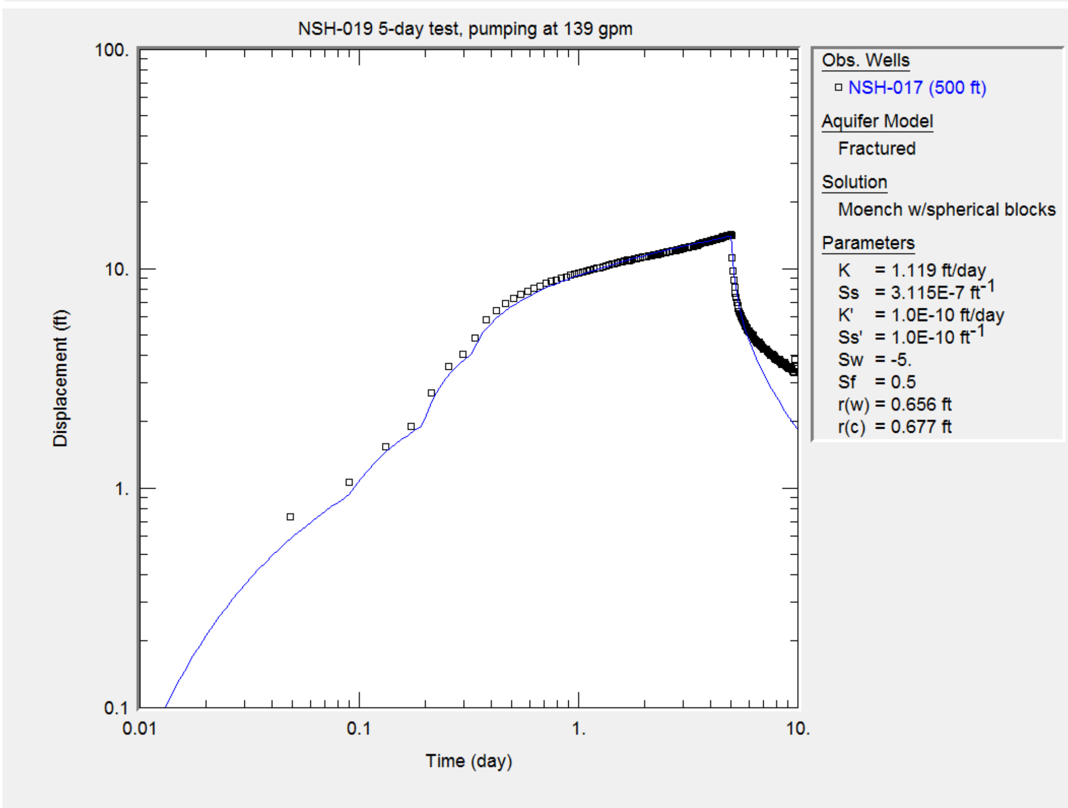


Figure 93

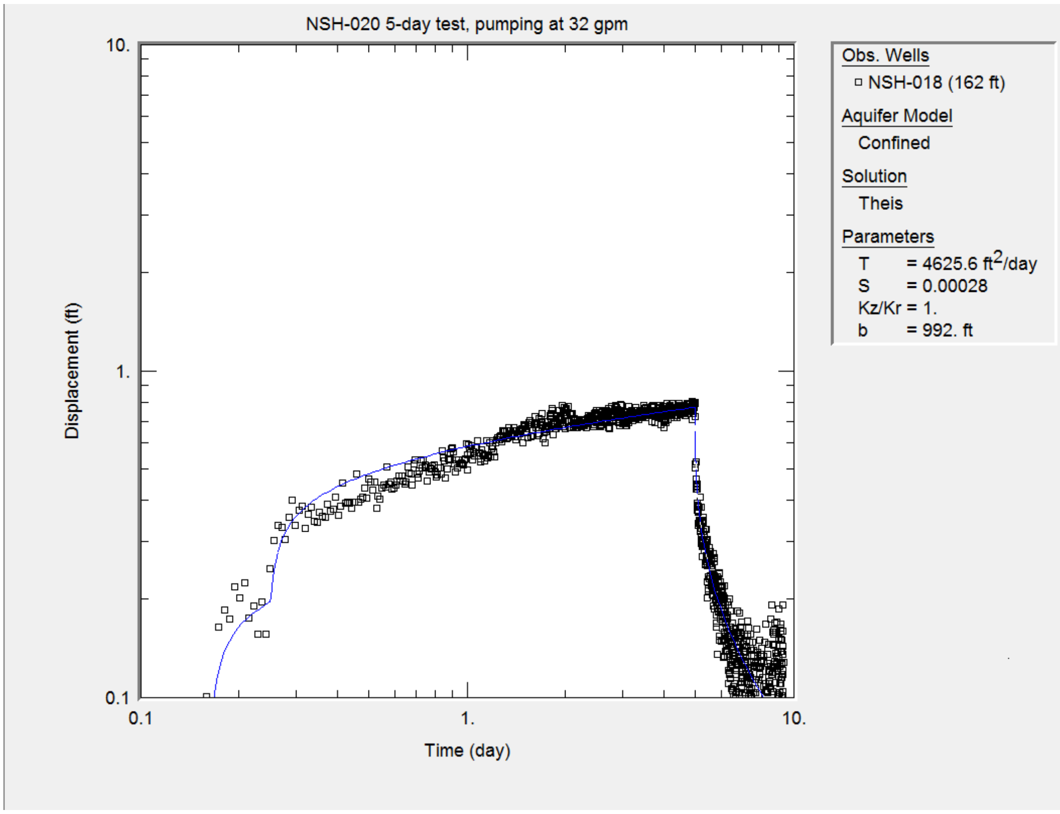


Figure 94

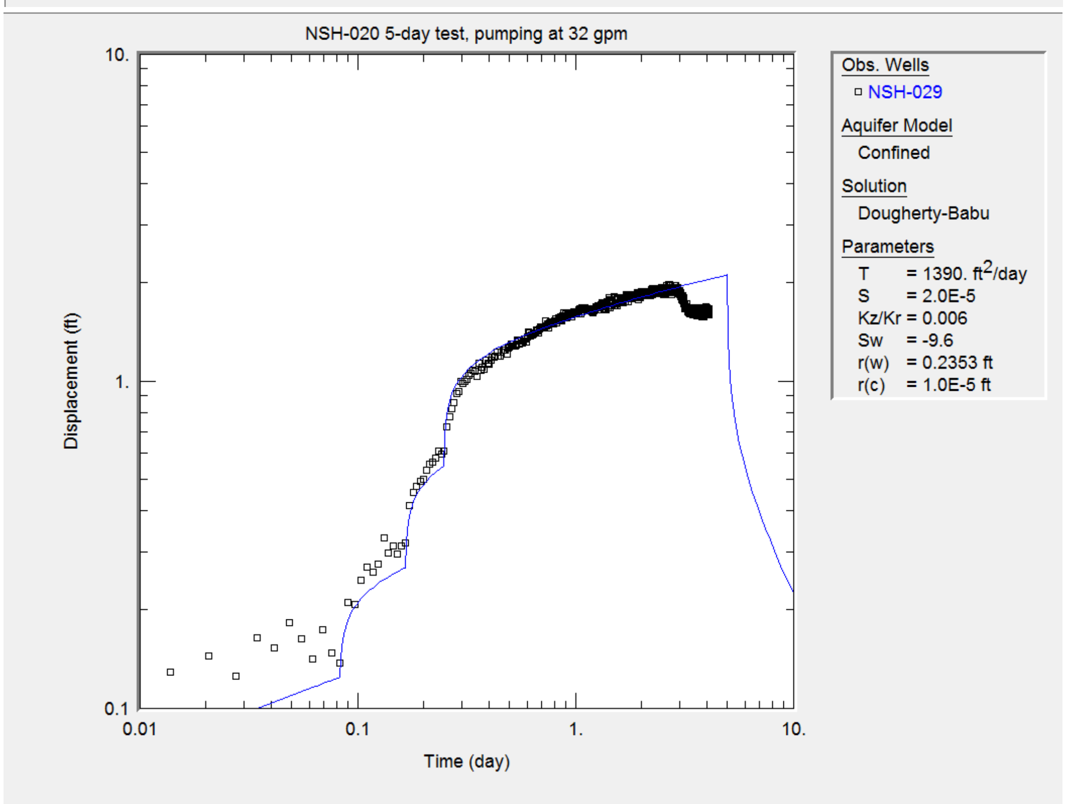


Figure 96

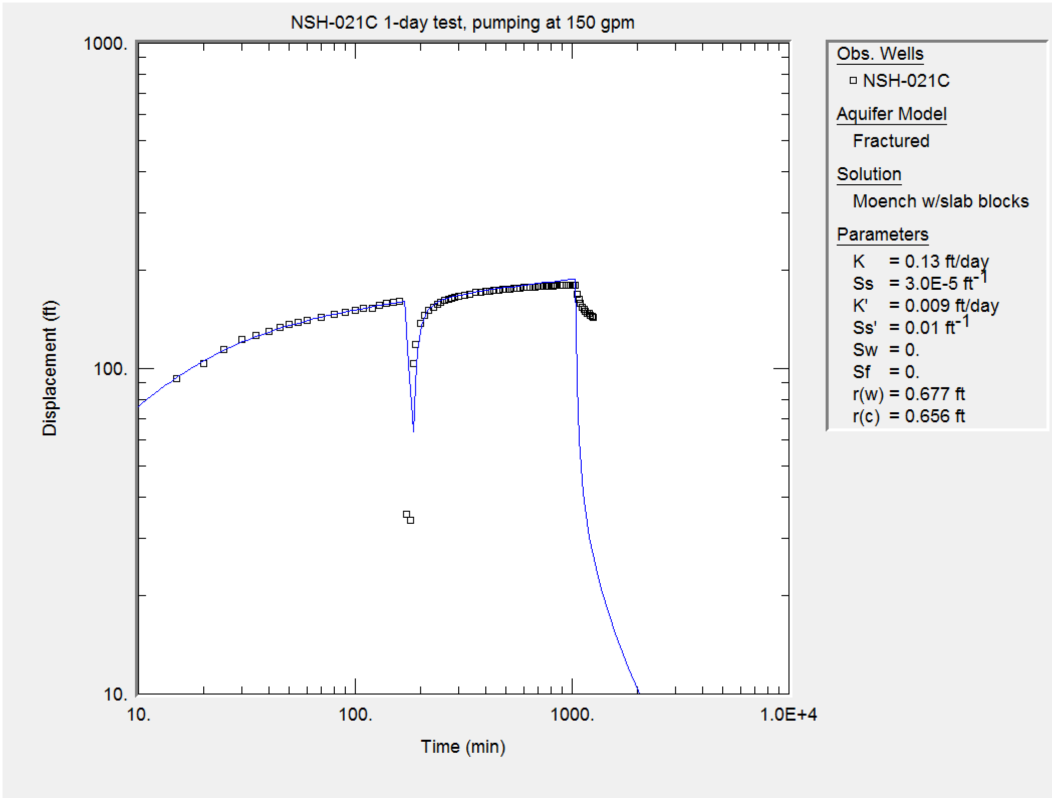


Figure 97

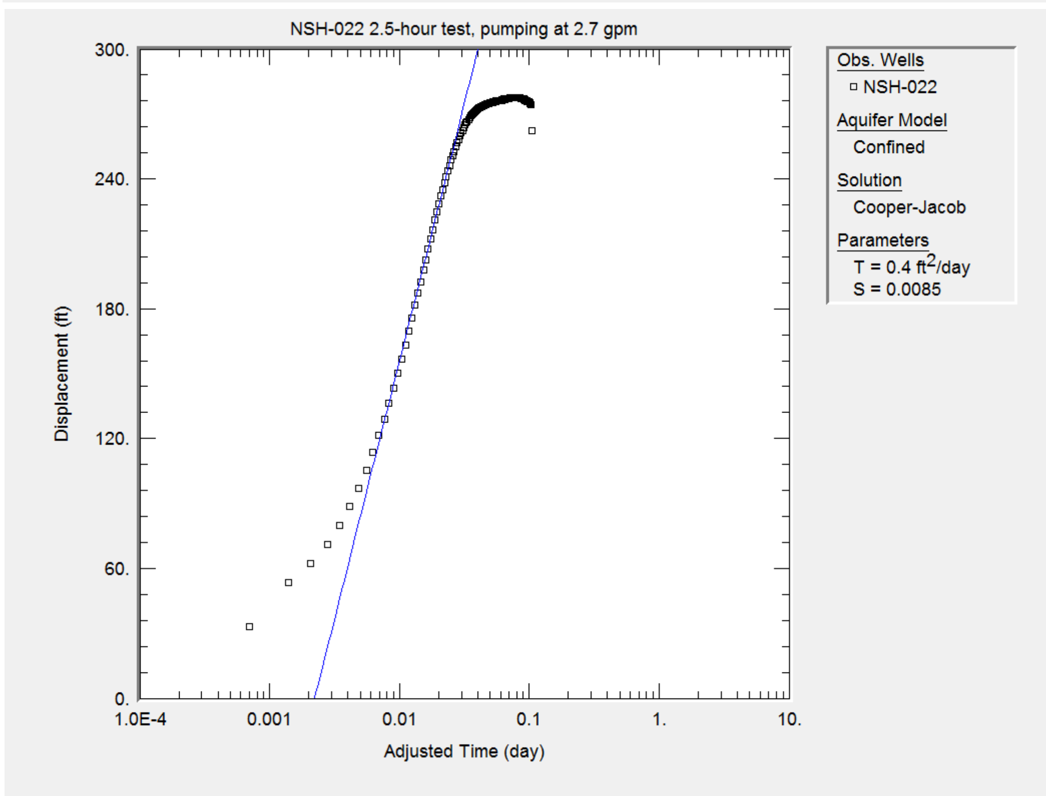


Figure 98

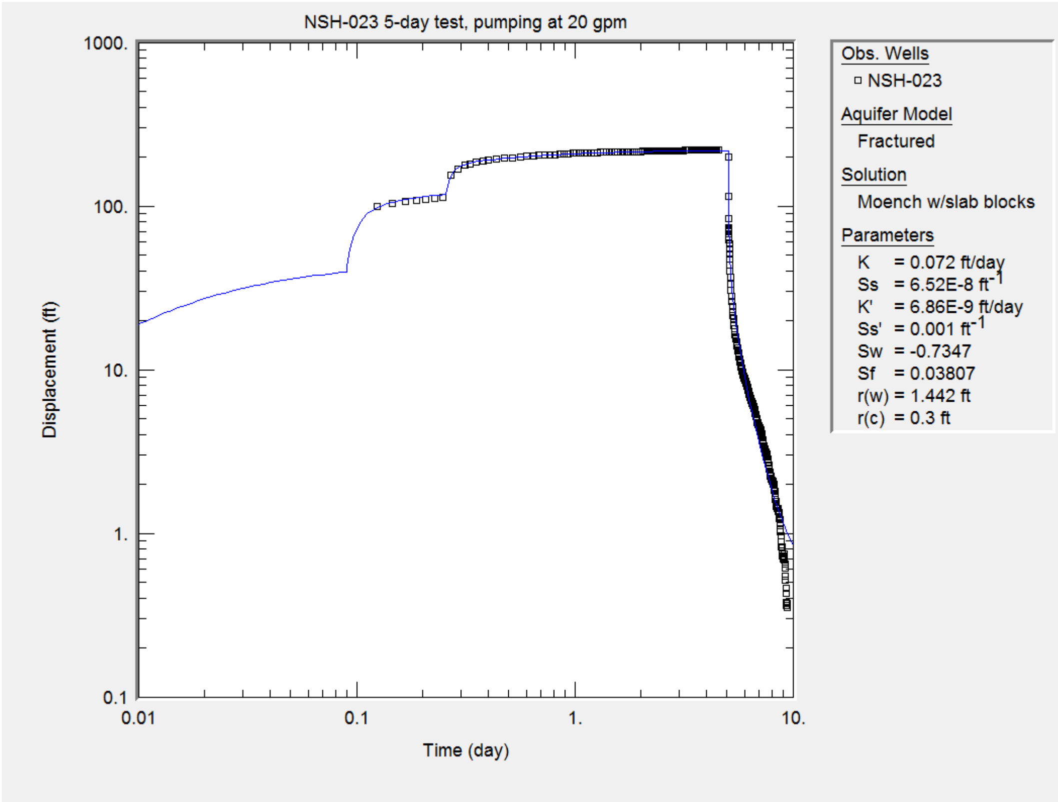


Figure 99

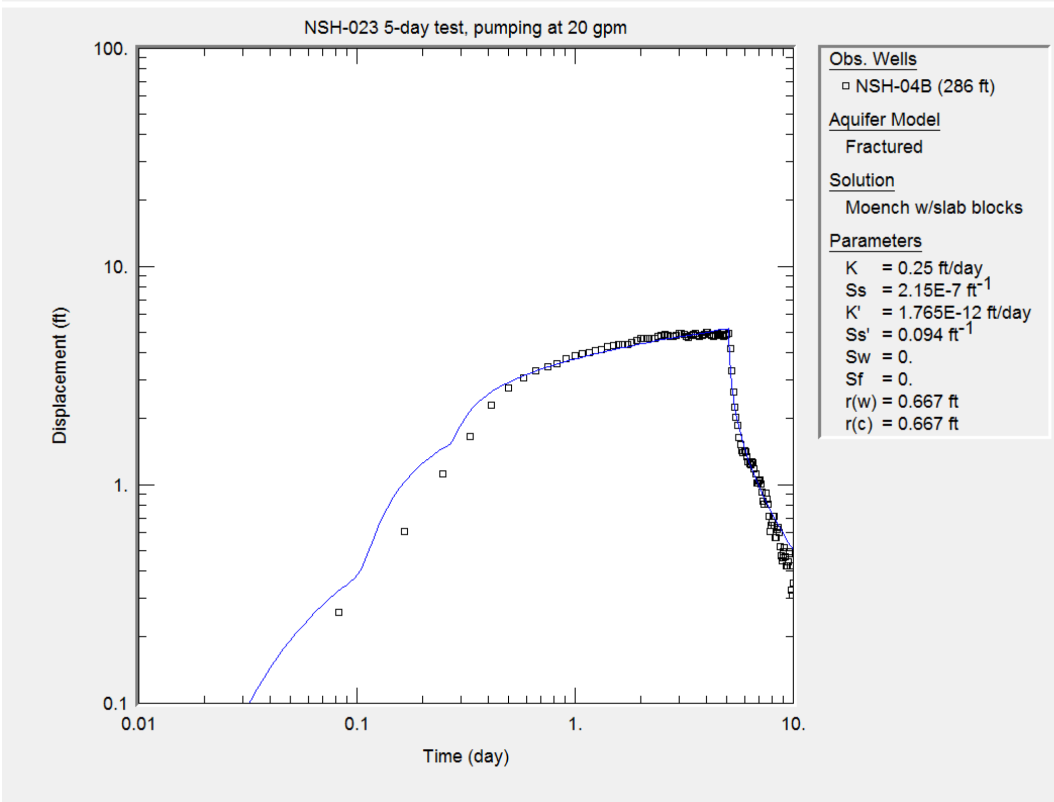


Figure 100

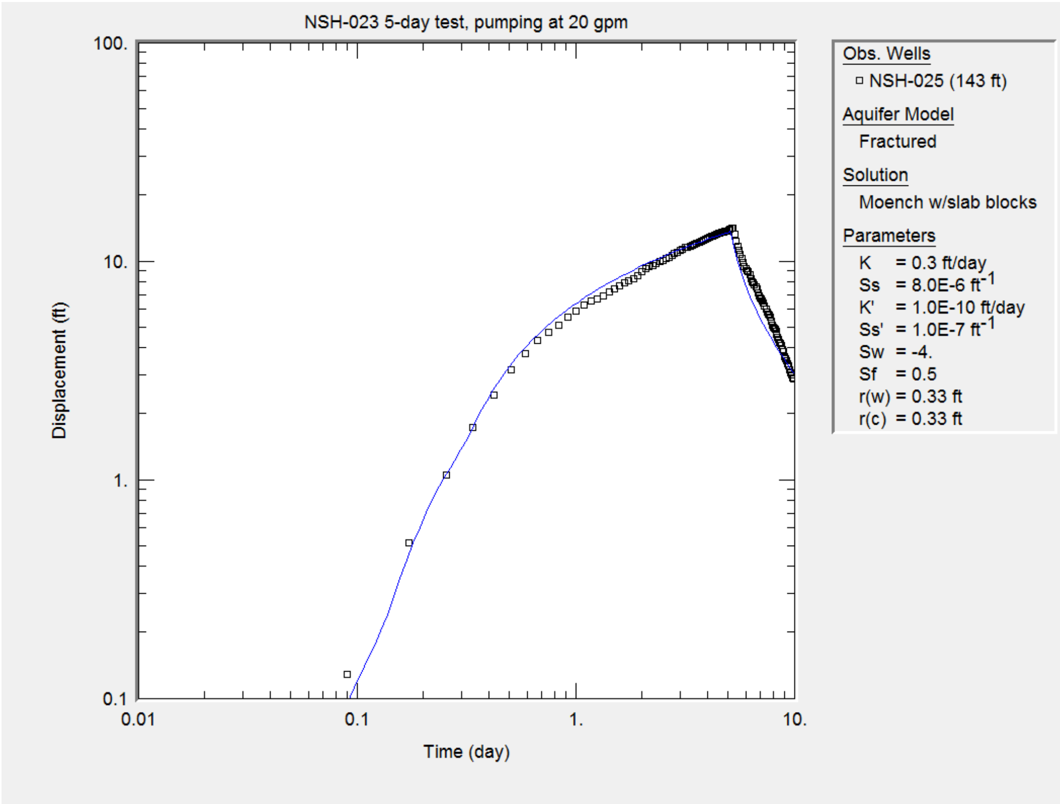


Figure 101

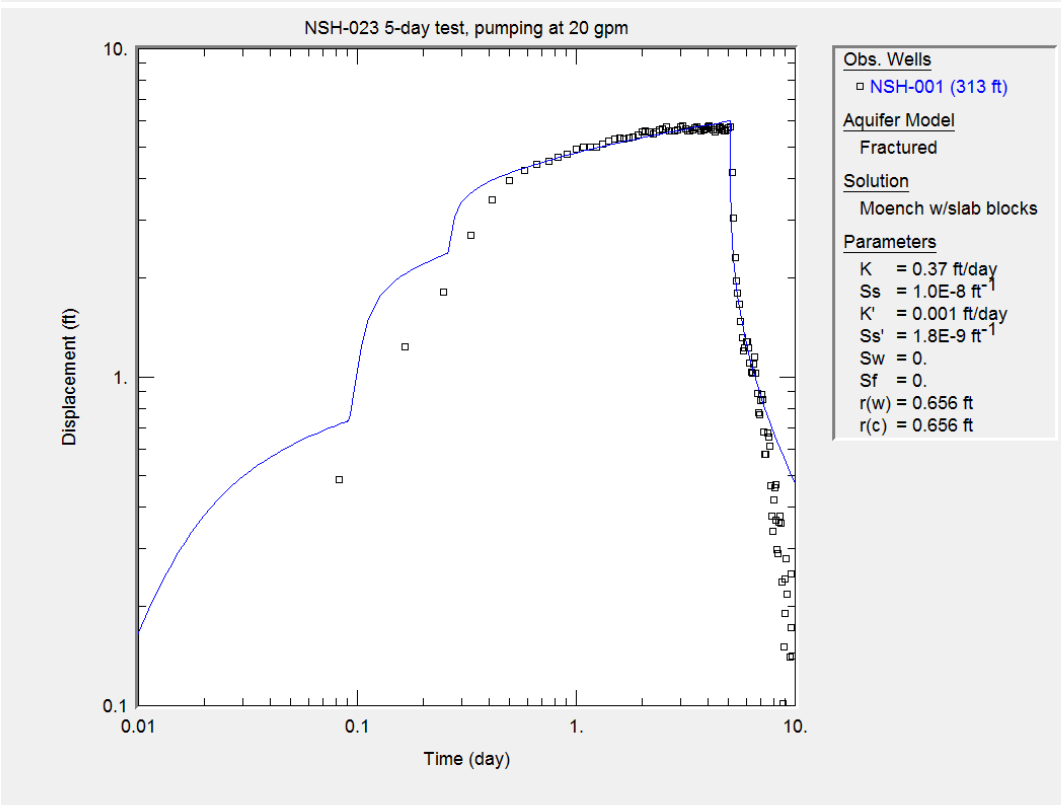


Figure 102

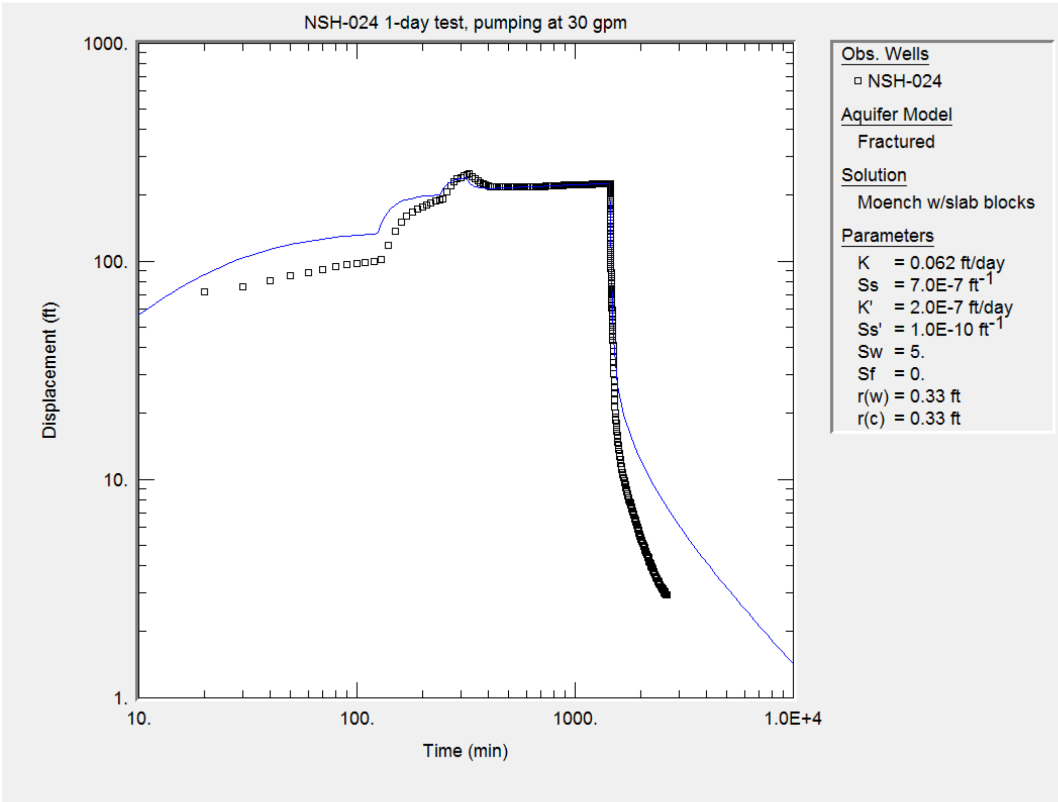


Figure 103

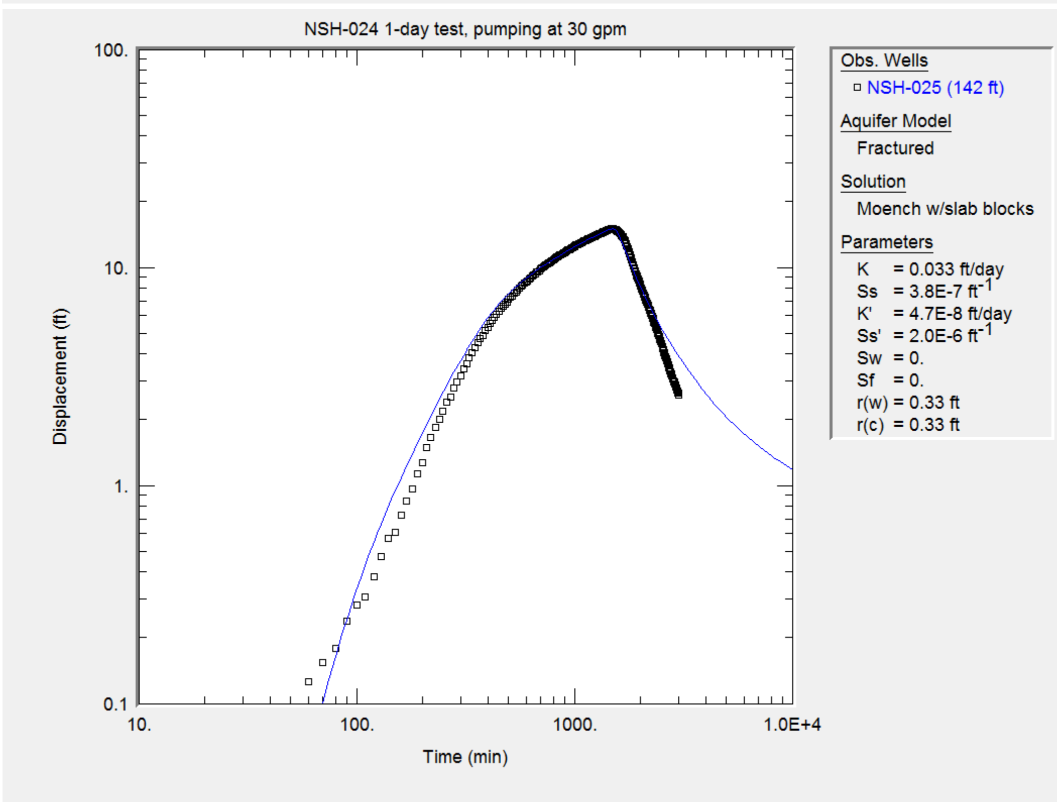


Figure 104

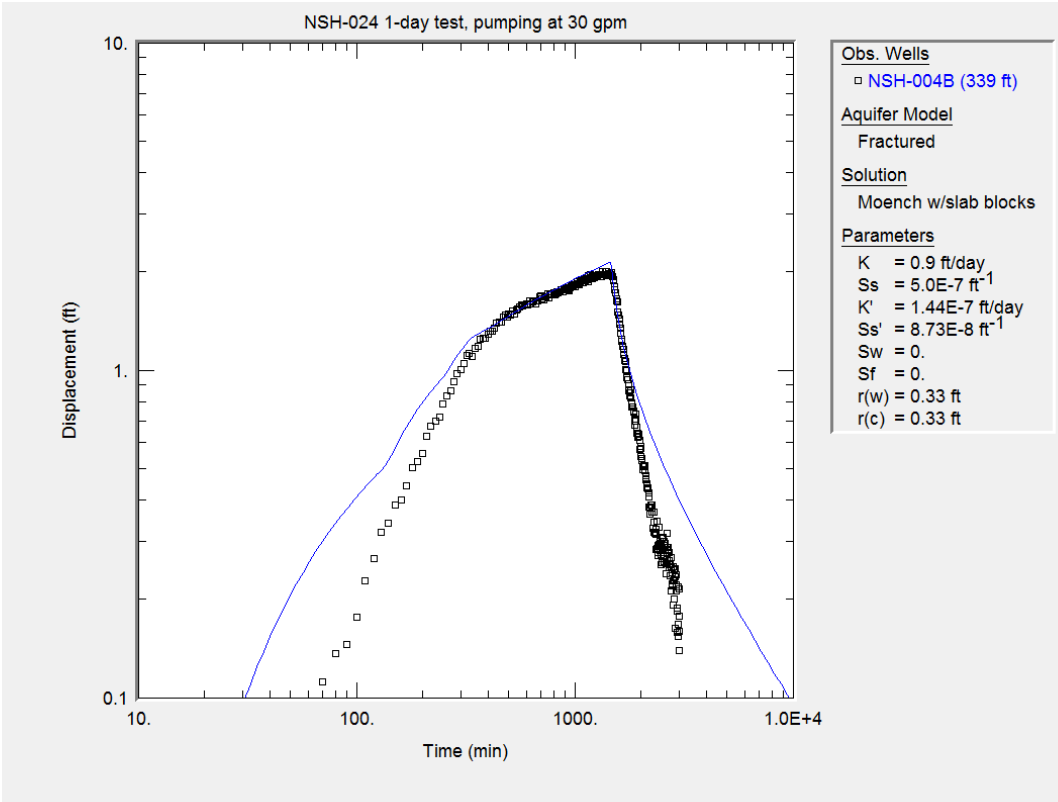


Figure 105

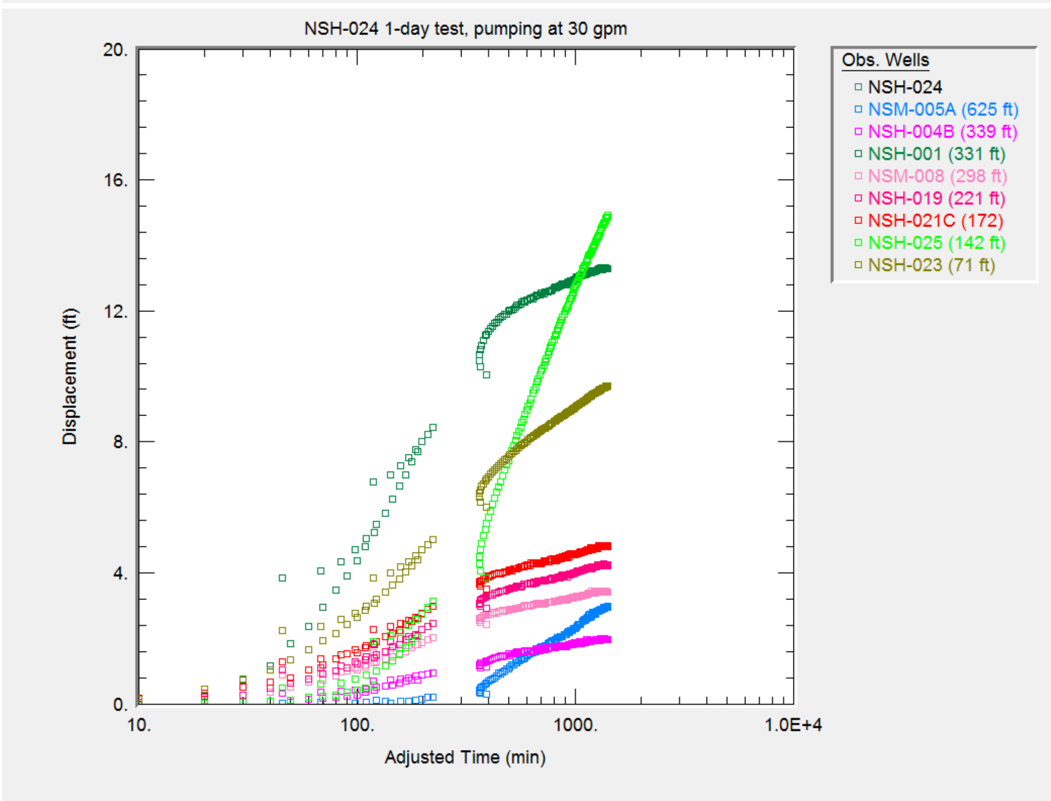
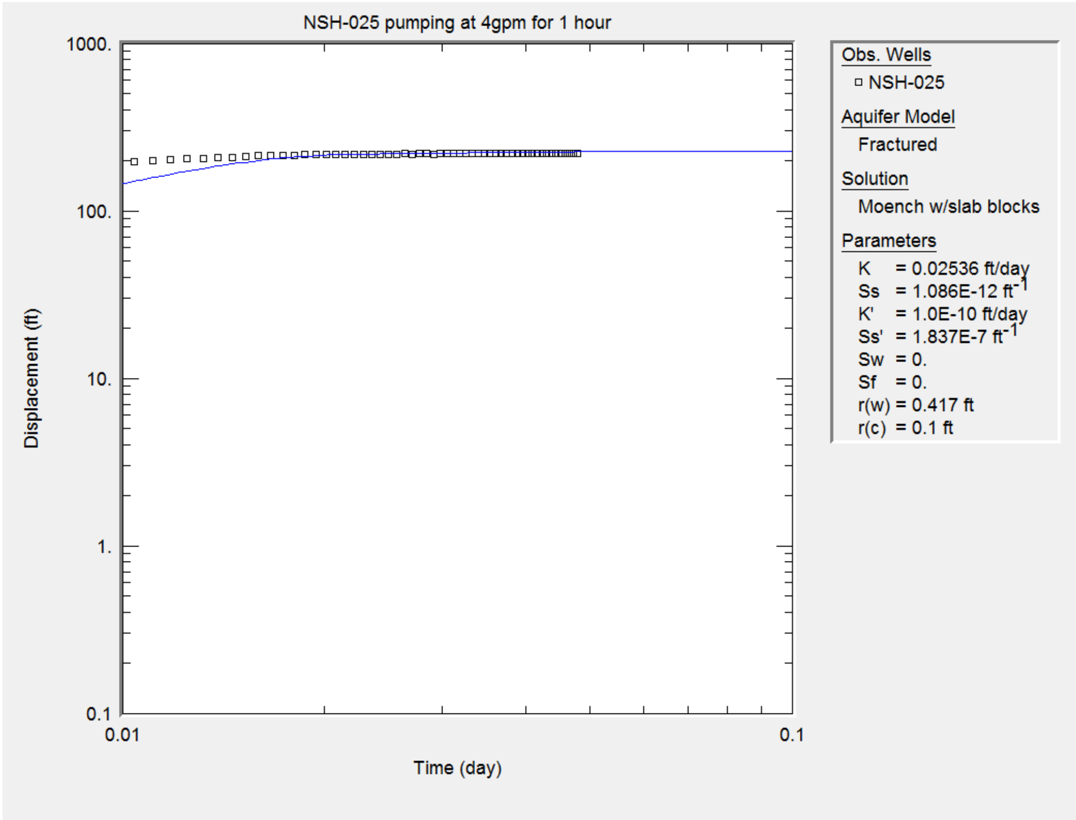


Figure 106



NSH-025 pumping at 4gpm for 1 hour
1000.
100.
10.
1.
0.1
0.01
0.1
Displacement (ft)
Time (day)
Obs. Wells
NSH-025
Aquifer Model
Fractured
Solution
Moench w/slab blocks
Parameters
K = 0.02536 ft/day
Ss = 1.086E-12 ft-1
K' = 1.0E-10 ft/day
Ss' = 1.837E-7 ft-1
Sw = 0.
Sf = 0.
r(w) = 0.417 ft
r(c) = 0.1 ft

Figure 107

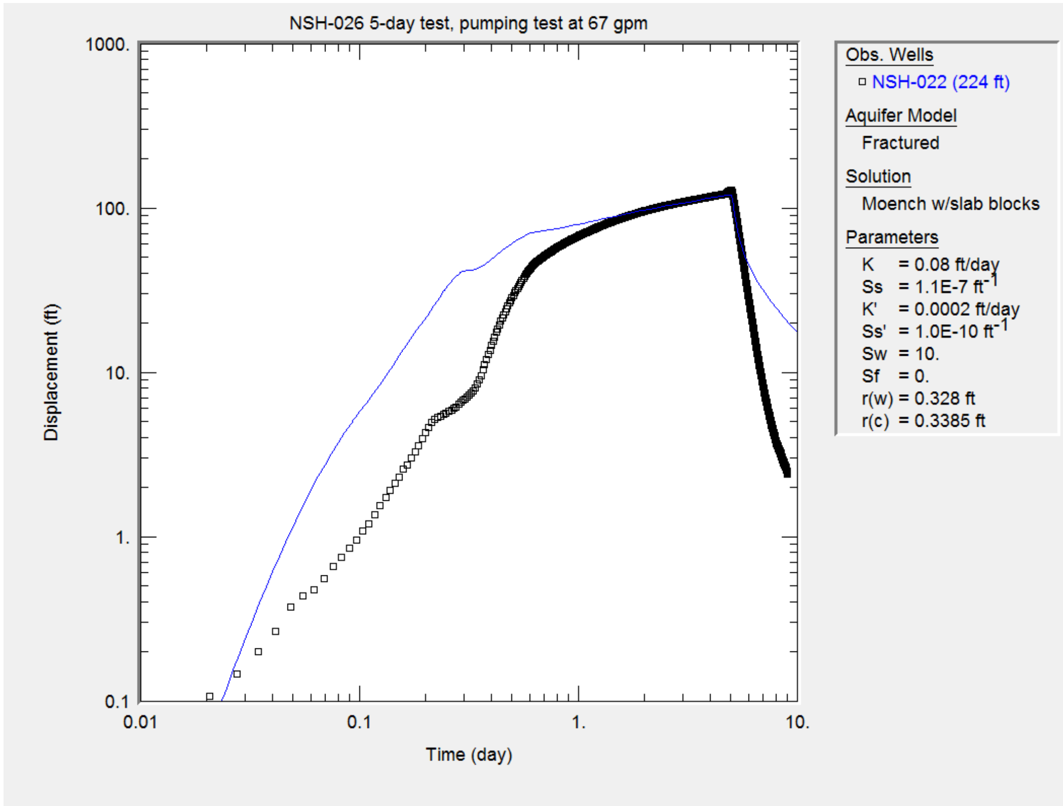


Figure 108

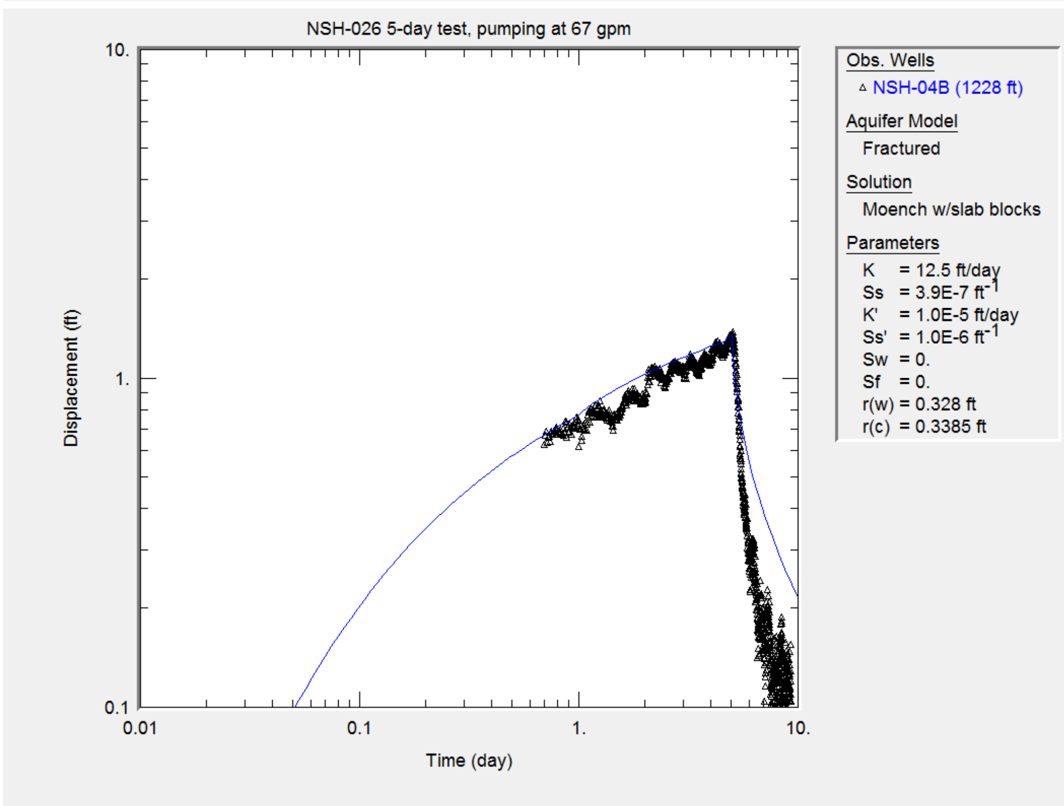


Figure 109

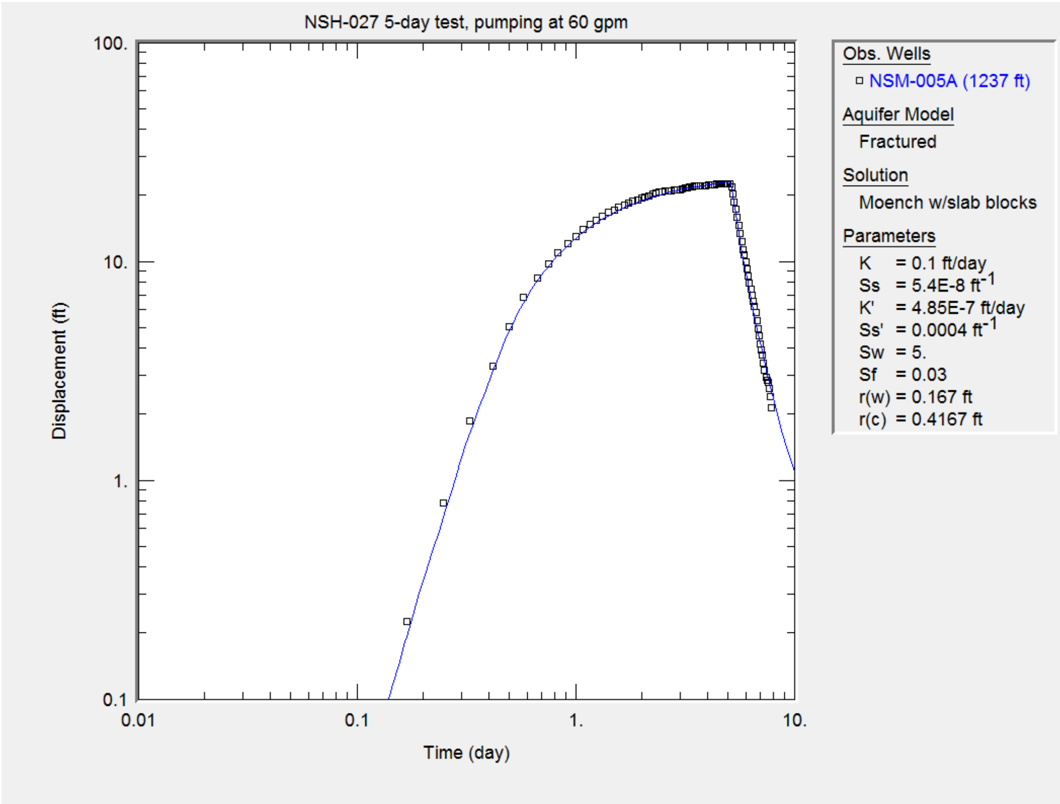


Figure 110

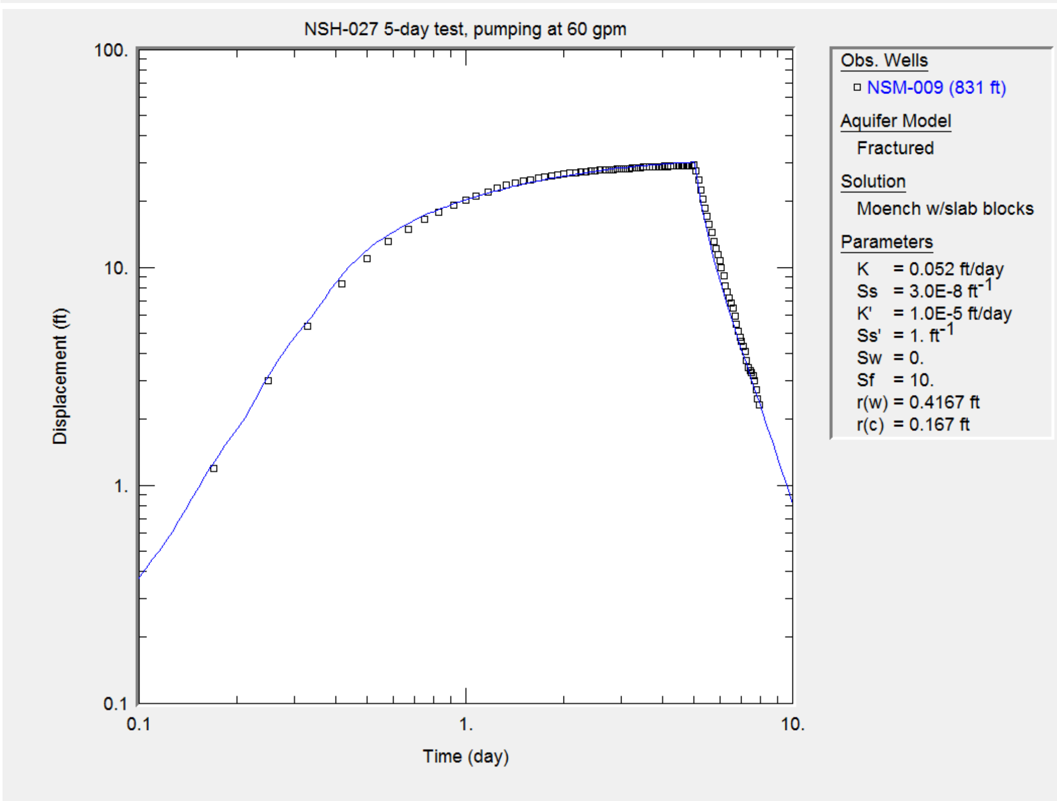


Figure 111

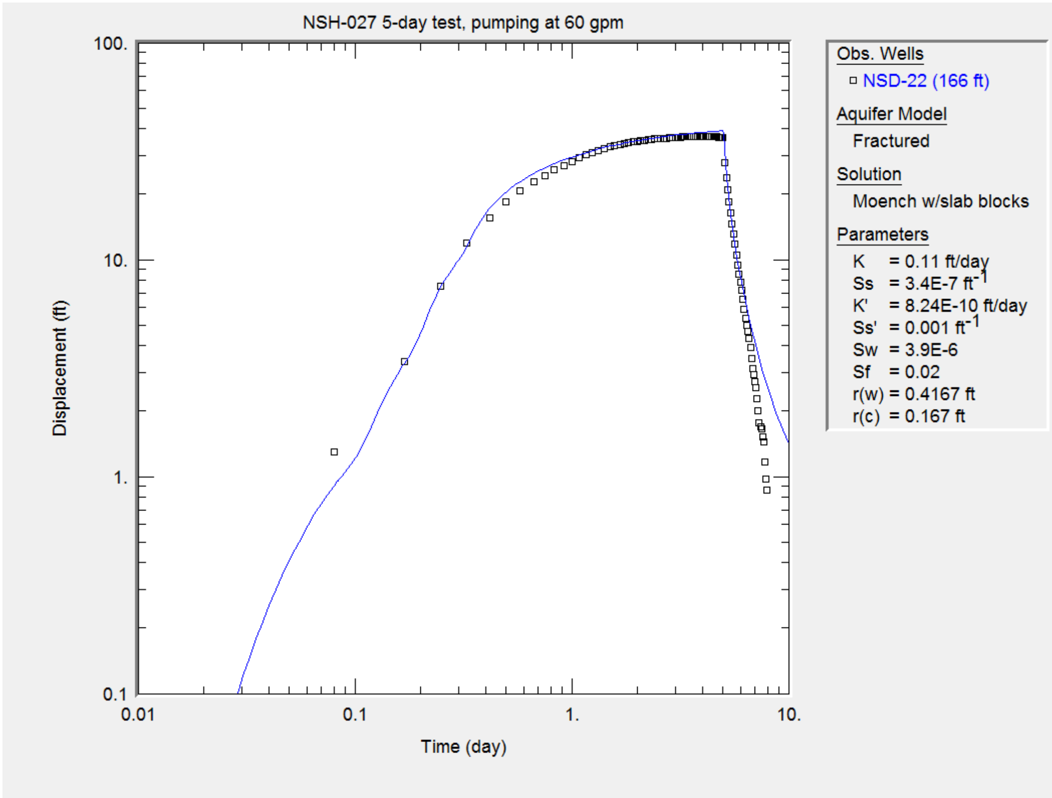


Figure 112

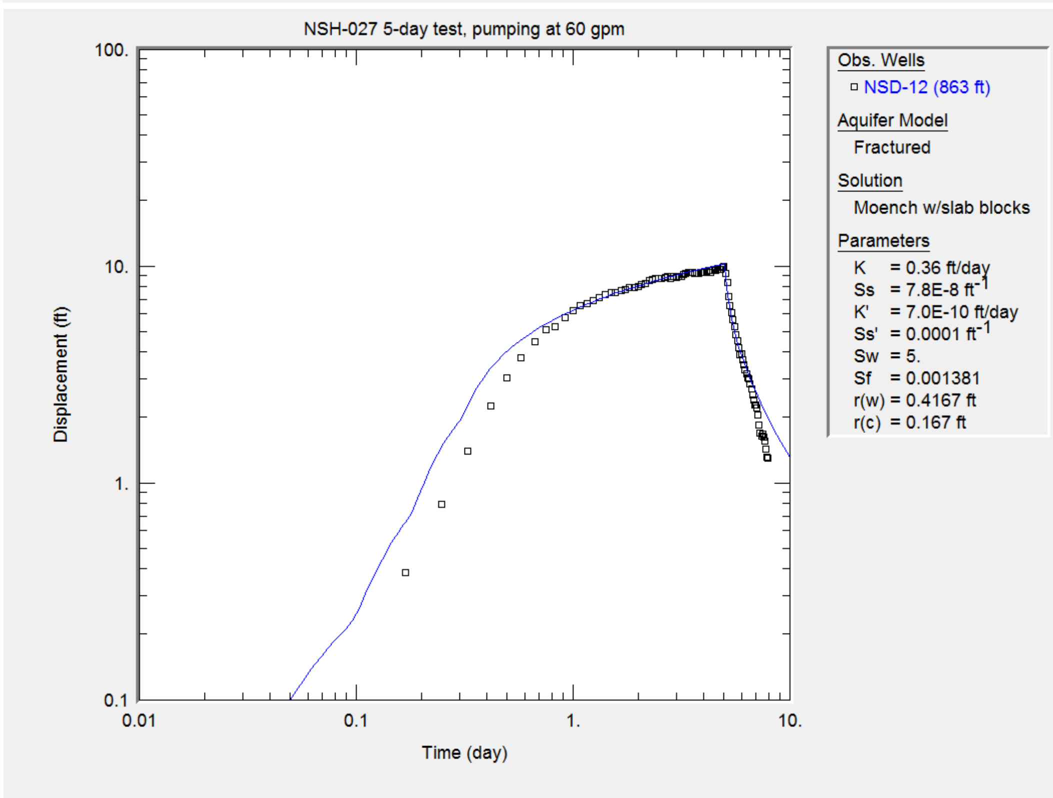


Figure 113

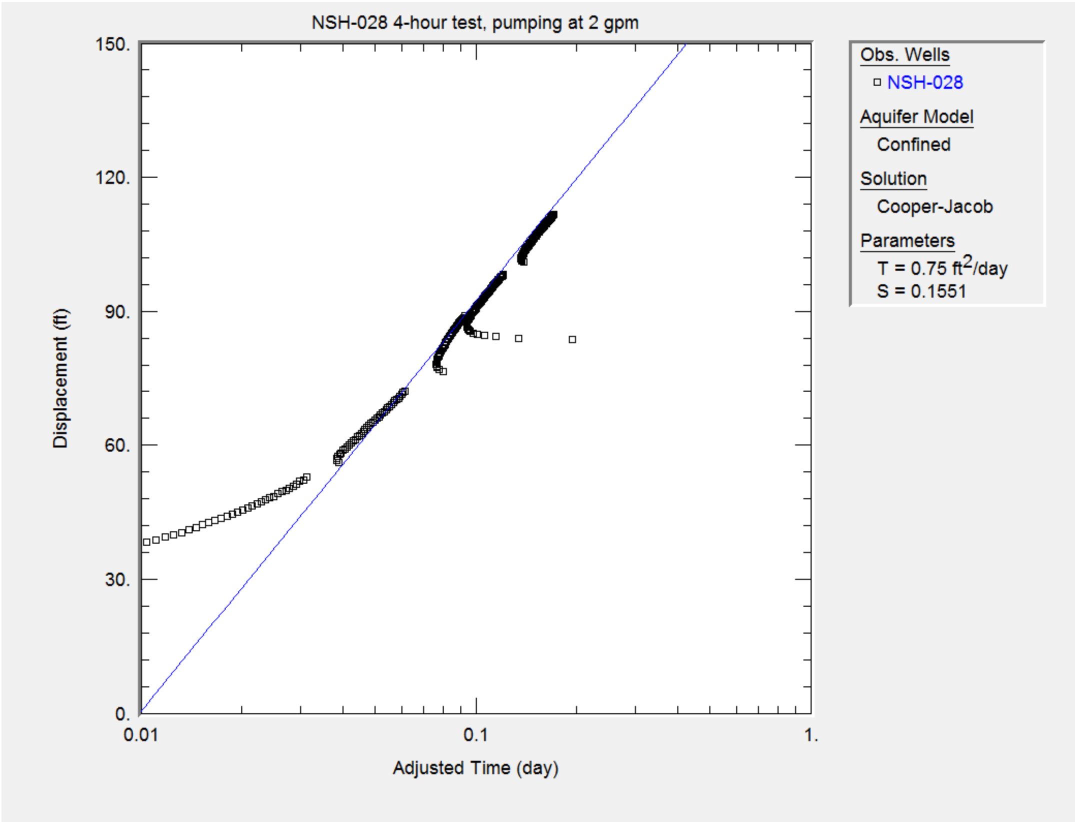

NSH-028 4-hour test, pumping at 2 gpm
150.
120.
90.
60.
30.
0.
Displacement (ft)
0.01
0.1
1.
Adjusted Time (day)
Obs. Wells
NSH-028
Aquifer Model
Confined
Solution
Cooper-Jacob
Parameters
T = 0.75 ft2/day
S = 0.1551

FIGURE 114 through 121.

STEP-DRAWDOWN TESTS –

WELL EFFICIENCY ANALYSES

Figure 114

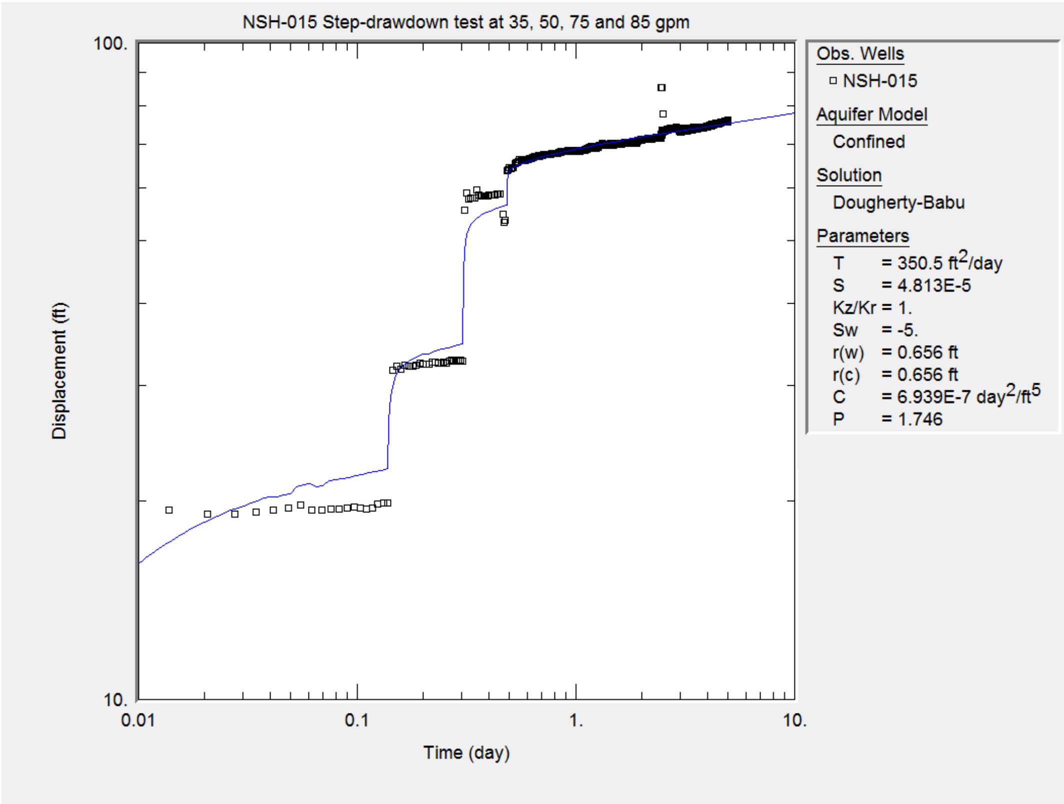


Figure 115

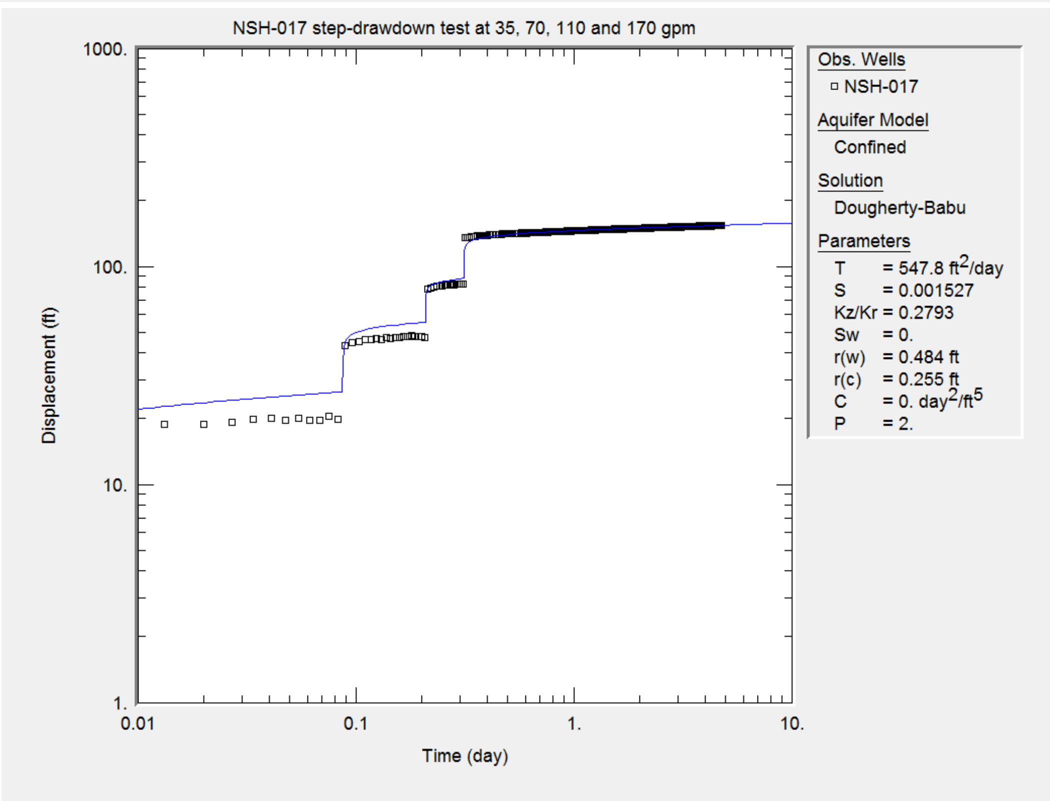


Figure 116

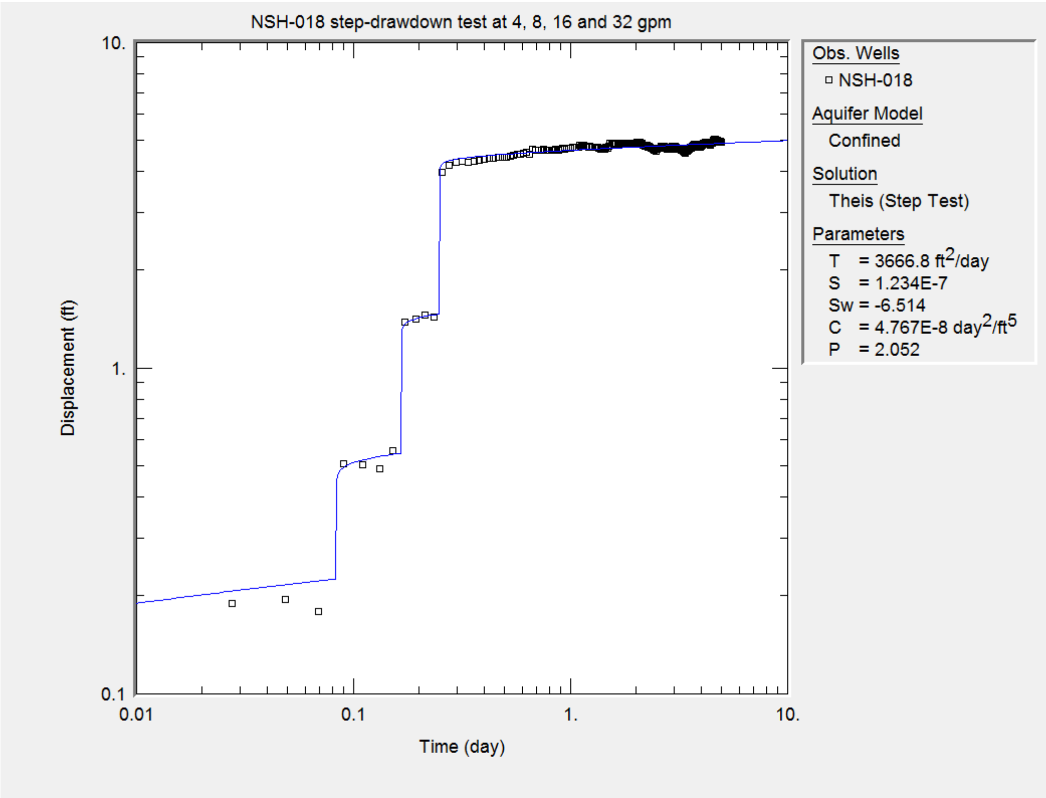


Figure 117

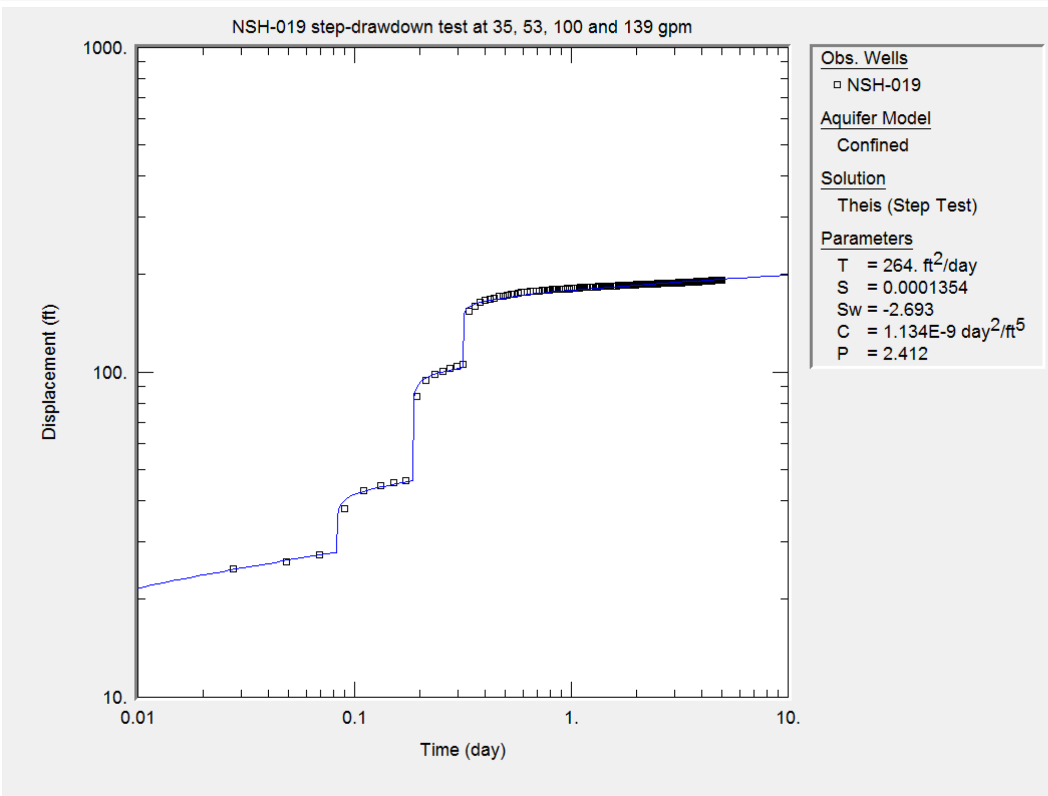


Figure 118

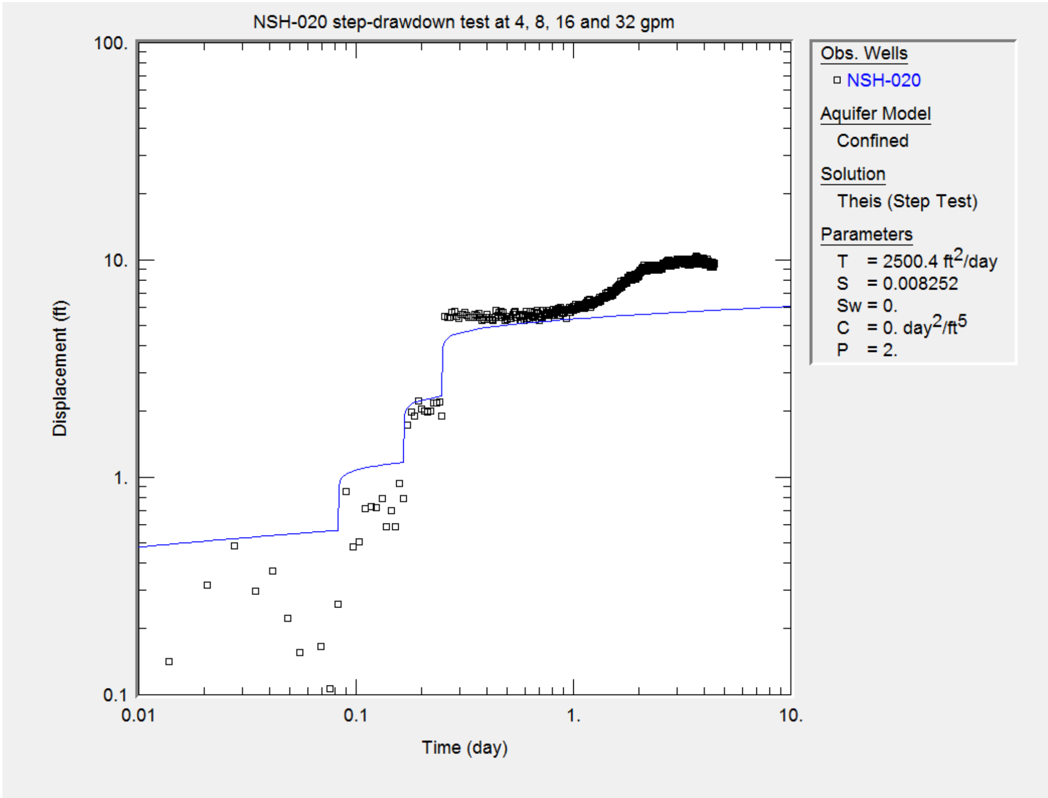


Figure 119

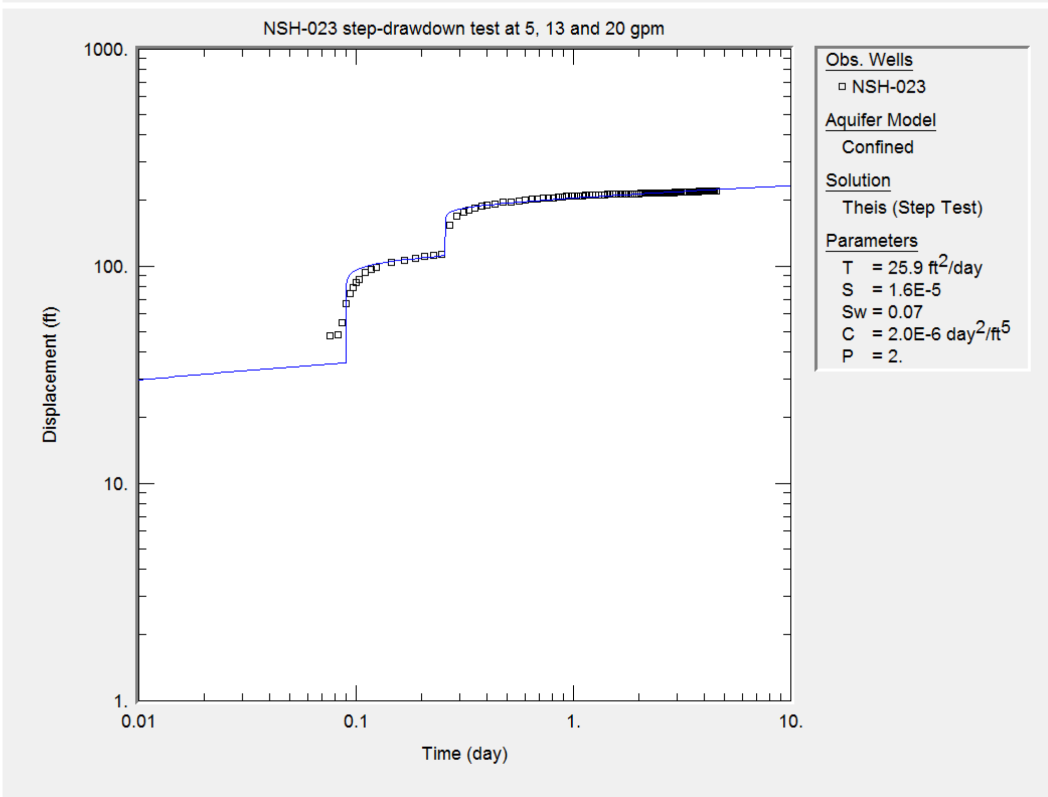


Figure 120

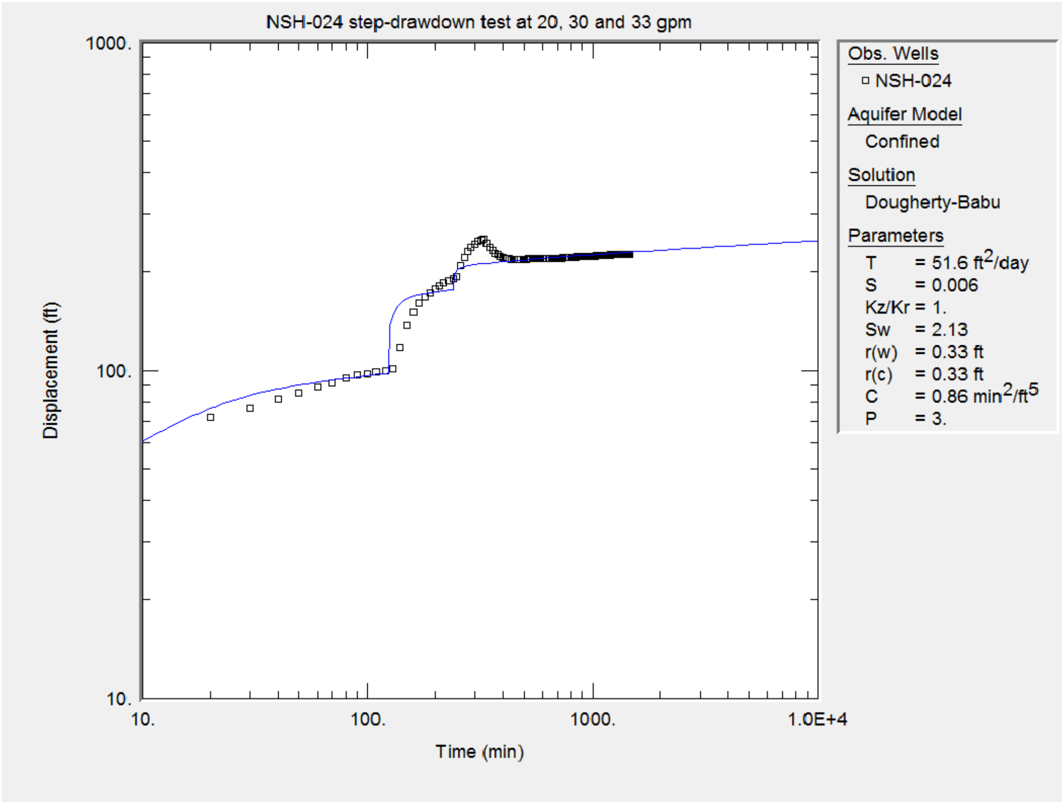
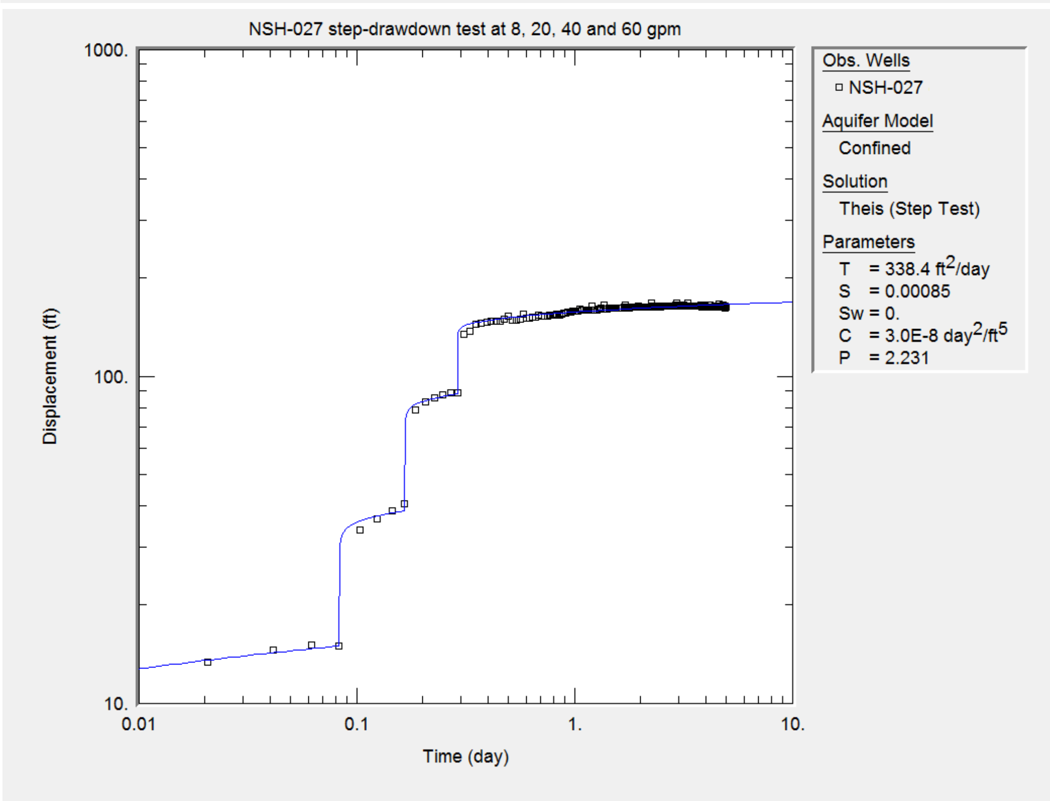


Figure 121



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Gunnison Copper Project
Aquifer Testing Report
January
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